A breakthrough recycling technology to transform technical textile waste into HIGH QUALITY RECYCLED PLASTIC
TABLE OF CONTENTS

EXECUTIVE SUMMARY ................................................................................................................................. 3

1. INTRODUCTION ........................................................................................................................................ 4
   1.1 The environmental challenge tackled by the project ................................................................. 4
   1.2 The Move 4earth® Project’s objectives and expected results ......................................................... 5
   1.3 The project partners ......................................................................................................................... 6

2. THE TECHNOLOGY .................................................................................................................................. 7

3. MAIN PROJECT ACHIEVEMENTS ........................................................................................................... 8
   3.1 Design and building of the demonstrator ......................................................................................... 8
   3.2 Validation and optimization of the recycling process ................................................................. 9
   3.3 Identification of valorization streams for the silicone residues ....................................................... 10
   3.4 Evaluation of the Move 4earth® technology to recycle other technical textile wastes .................... 11
   3.5 Assessment of the environmental impacts of the process and the benefits of the newly created recycling stream based on a Life Cycle Analysis methodology ........................................... 13

4. PROJECT ENVIRONMENTAL BENEFITS AND NEXT STEPS .............................................................. 15
   4.1 Environmental benefits ................................................................................................................... 15
   4.2 Next steps ...................................................................................................................................... 15
EXECUTIVE SUMMARY

The demand for more recycled plastics is growing in all European markets, including in the automotive industry, as legislators are calling for more efforts to recycle waste plastics and consumers progressively want more eco-designed products. Recycled plastics offer good environmental performances and reduce our dependency to fossil resources.

The Move 4earth® project has been launched by Solvay with an intention to contribute to a more circular economy, by demonstrating an industrial recycling solution for thousands of tons of technical textiles such as silicone coated airbag fabrics, and at the same time creating a new range of high-quality recycled plastics offering breakthrough environmental benefits for eco-designed applications.

The project had 4 main objectives:

1. **Reach a target throughput under stable processing conditions:**
   - Validation of elementary operations as a first step.
   - Validation of the entire continuous process at nominal throughput during a 48H test run.

2. **Produce a high-quality recycled polymer:**
   - Purified from silicone residues.
   - Offering stable properties like virgin PA66 and suitable for Technyl® 4earth® compounds.

3. **Minimize the environmental impacts of the Move 4earth® process** and demonstrate the low environmental footprint of the recycled plastics made from that technology using Life Cycle Assessment methodologies.

4. **Identify and validate recycling solutions and applications creating value for the silicone waste** generated by the process after its separation from the polyamide (up to 15% of the flow).

As it will be depicted in the following sections, the project has delivered on all its key objectives and the project partners intend to pursue their efforts, considering among others the following future perspectives:

- Scale-up projects and collaboration with partners to explore future post-consumer airbag collection and recycling streams.
- Design for recycling projects aiming at redesigning some technical textiles with PA66/silicone fabrics in order to make them recyclable with the Move 4earth® technology.
1. INTRODUCTION

1.1 The environmental challenge tackled by the project

The needs for high quality recycled polyamide plastics are expected to grow very significantly in the coming years in all European markets, including in the automotive industry. The reasons for this trend are both i) environmental and ii) economical. Consumers want more eco-designed products and understand that recycled materials offer good environmental performances. Recycling waste plastics is a way to conserve resources and an essential component of the circular economy. At the same time, recycled products are less dependent to fossil and petroleum-based intermediates, which prices have been rather volatile and constantly increasing over the last years.

Industrial companies understand that future legislation might impact their business soon following the announcement of the European Plastics Strategy in January 2018 calling for more recycling and less landfilling of plastics in Europe. The aim is to achieve much higher levels of plastics recycling and to minimize the extraction and transformation of natural resources, in view of a sustainable growth in Europe.

Therefore, it is more than ever important to create new technologies aiming at developing high quality recycled plastics suitable for technical applications for which there is no offer yet on the market. To meet this growing demand, such technologies must be invented to enable the recycling of waste for which there is currently no sustainable recycling option available. It is also very important to make sure that such new technologies generate significantly less impacts (CO2 emission, energy consumptions, water consumption etc.) on the environment than the traditional processes in place to produce virgin products.

In automotive, the directive 2000/53/EC sets an 85% target by 2015 for reuse and recycling of post-consumer cars, but no sustainable solutions exist for airbag. More than 70% of airbags cushions produced in the world are made of polyamide (PA) fabrics coated with silicone (Si). In Europe, this industry generates around 9000t of such fabrics wastes every year.

In this context, Solvay has decided to develop the Move 4earth® technology aiming at recycling fabrics scraps generated during the production of airbag cushions (as the pilot case) before expanding it to other similar types of waste in the future.

By separating the polyamide yarns from the silicone coating, the Move 4earth® technology makes it possible to recover a high-quality recycled polyamide polymer from silicone coated airbag fabrics.

This innovative recycling process leads to breakthrough environmental benefits, of which lower CO2 emissions, lower primary energy consumptions, and lower water consumptions.

In the future, the scope of this new recycling solution could expand to post-consumer airbag cushions. As a result of the fast-growing number of airbags in modern cars globally, post-consumer streams of airbag wastes are expected to represent very significant potential volumes of waste in the next decade. Currently, airbag cushions present in end-of-life vehicles are neither reused nor recycled, and do not contribute to reach the recovery targets set by the European End-of-Life Vehicle Directive (Directive 2000/53/EC) for recycling of vehicles and components.

![Image of recycled polyamide process]
1.2 The Move 4earth® project’s objectives and expected results.

The Move 4earth® project has been launched with an intention to contribute to a more circular economy, by demonstrating an industrial recycling solution for thousands of tons of technical textiles such as silicone coated airbag fabrics, and at the same time creating a new range of high-quality recycled plastics offering breakthrough environmental benefits for eco-designed applications.

A video presenting the overall project can be found at the following link:
https://www.youtube.com/watch?v=9W0egwElXI0.

The industrial objectives of the project were the following:

1. Reach target throughput under stable processing conditions:
   • Validation of all elementary operations
   • Validation of the entire continuous process at nominal throughput

2. Produce a high-quality recycled polymer:
   • Purified
   • Stable properties near to traditional Technyl® polymer
The environmental objectives of the project were the following:

1. Prove the environmental efficiency of the technology through Life Cycle Analysis and minimize energy and water consumption.
2. Validate value-creation options for the silicone residues (up to 15% of the flow).

### 1.3 The Project partners

<table>
<thead>
<tr>
<th>Entity</th>
<th>Location</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhodia Operations S.A.S.</td>
<td>France (Saint-Fons)</td>
<td>Part of the Solvay Group, which is a world leader in specialty chemicals including polyamides. The company counts manufacturing facilities and R&amp;D centers in France. The recycling process has been first designed in France before being implemented in Gorzow, Poland.</td>
</tr>
<tr>
<td>Solvay Engineering Plastics Poland Sp. Z.o.o</td>
<td>Poland (Gorzow)</td>
<td>Solvay EP Poland main activity is the production of polyamide 6 and compounds based on polyamide 6 and other polyamide polymers delivered from other site of the Groups. Part of the production are recycled compounds made from recycled polymers sourced internally or externally. The Move 4earth® unit has been implemented on this site.</td>
</tr>
</tbody>
</table>
2. THE TECHNOLOGY

The technology combines mechanical and chemical processes in a continuous intensive process able to achieve a very good separation of the silicone coating from the polyamide yarns contained in airbag fabrics.

Once purified, the recycled polyamide 66 polymer becomes the main raw material for Technyl® 4earth®, a new range of high-quality engineering plastics dedicated to eco-designed applications in various industries such as automotive, construction, and consumer appliances.
3. MAIN PROJECT ACHIEVEMENTS

The main activities performed during the project can be summarized as follows:

3.1 Design and building of the demonstrator

This action was implemented in two steps:

1. A detailed engineering study has been conducted mainly to define detailed specifications for each process equipment and design the layout of the demonstrator. Results from preliminary process validation tests (see 3.2) were useful to determine robust specifications for some equipment.

2. Based on the detailed engineering study, a building was renovated and upgraded to be ready to host the demonstrator. Then all pieces of equipment have been purchased and installed until the Mechanical Completion was reached in July 2016. This was the ultimate milestone for this phase which has involved many experts from Solvay (Engineering, R/D, maintenance, production...) but also engineering and construction contractors.
3.2 Validation and optimization of the recycling process

The first step within this phase was the discontinuous validation of all main equipment and process steps individually. This has been completed in April 2015, even before launching the detailed engineering and construction of the demonstrator. The pre-commissioning of the demonstrator was started immediately after its mechanical completion. After multiple test runs have been performed, the demonstrator’s process has been considered as validated in April 2017 at an intermediate throughput not yet corresponding to the full capacity.

Then the process has been ramped-up and continuously optimised until September 2018 when the targeted throughput and OEE were reached and even exceeded during a 48 hours stable test run. During this trial, not only the technology was fully demonstrated as being industrially robust and ready for future scale up, but also the high quality of the polymer and the compliance of the liquid effluents generated by the process were also validated.

On top of demonstrating the industrial performances of the process, it was fundamental to identify high value applications for the recycled polymer. Therefore, a new range of Technyl® 4earth® high quality recycled compounds has been created and successfully promoted until commercial applications were launched in various markets such as automotive, building and construction, and consumer appliances.

Cylinder head cover in the automotive market
High pressure lances for gardening tools
Window profiles in the building and construction sector
3.3 Identification of valorization streams for the silicone residues

To minimize the environmental impacts of the technology, the objective of this action was to explore valorization options for the silicone residues generated during the recycling of silicone coated airbag fabrics.

A first solution was rapidly identified and implemented. It consisted in mixing the silicone residues with other Solid Recovered Fuels (SRF) used to produce energy.

Then many efforts have been put on finding other valorization streams with the objective to recover the material and give it a second life.

Overall more than 40 prospects have been identified and contacted within and along several value chains involved with various applications such as plastics, elastomers, transportation infrastructures, building and construction, etc.

One first application was finally identified and consists in using the silicone residues into the composition of booster additives to be mixed with polyolefins to produce various applications such as flower pots, post mail boxes or light roofing systems.

Investigations of other promising valorization streams are still going on and will be pursued after the end of the project.
3.4 Evaluation of the Move 4earth® technology to recycle other technical textile wastes

The objective of this action was to further demonstrate the technology for 2 alternative raw materials:

1. post-consumer airbag cushions
2. polyamide/elastane fabrics.

With regards to post-consumer airbags, the project has addressed the following topics/challenges:

- How should post-consumer airbags be dismantled from end-of-life vehicles?
- What are the available volumes and related costs?
- What is the quality of the recycled polymer?
- Where could the first post-consumer dismantling streams emerge?
- What is the economic viability of the targeted streams?

The project findings have demonstrated that it is possible to recycle post-consumer airbags with the Move 4earth® technology:

- The preferred way to dismantle airbag cushions would be without inflating them in order to avoid leaving any substances on the cushions. However, this option seems to be difficult and costly given the way an airbag module is designed and what it takes to remove the cushion from the module. A complete change of design would be necessary to make such a dismantling possible, however it is very unlikely that car makers would agree to do this in a coordinated manner without new legislation, and even if they would, the effect would only be visible at dismantlers in 15 years from now.
- Inflating the airbags before cutting them out seems to be the most cost-efficient option. Whilst it is hardly economically viable in Western Europe yet, it seems viable in other areas with lower labour costs.
- 3 tons of dismantled cushions have been processed at the Move 4earth® demonstrator without major process difficulties.

![Dismantled airbag cushions as delivered in a big-bag.](image)

- The quality of the recycled polymer obtained from this first trial was found at a slightly lower level compared to the one made from post-industrial scraps, but still enough to envisage future optimizations for technical compounds.
It is now the intention of the Move 4earth® project team to start new collaborations in order to determine how to make the recycling of post-consumer airbags happen at a large scale in Europe. New solutions must be invented to reduce dismantling costs and optimize the waste collection.

When it comes to PA/elastane waste streams, since elastane yarns are commingled with thinner interwoven polyamide fibers, the separation of both materials is particularly complex and challenging.

A two steps approach has been considered: the first step was to grind the product with the objective of untangling the two polymers and a second step to do the separation using Move 4earth® centrifugation equipment.

Multiple trials were performed to assess feasibility to separate the 2 materials by changing all possible process parameters without success. Whatever the process condition tested, no separation of the two solids was observed.

The recyclability of PA/Elastane fabrics with the Move 4earth® technology could not be demonstrated. It appeared that the combination of mechanical downsizing and liquid separation was not the right technological route for this waste stream.
3.5 Assessment of the environmental impacts of the process and the benefits of the newly created recycling stream based on a Life Cycle Analysis methodology

This action aimed at ensuring that the recycling process complies with the sustainable development objectives of Solvay. Ensuring a proper treatment of effluents was a critical deliverable of this action. The environmental impacts of producing recycled PA were also assessed and compared to the usual production of PA66 through a Life Cycle Analysis (LCA).

After thorough investigations at an early phase of the project, the technical solution for disposing liquid effluents has been defined and validated. This solution consists in a specific filtration of the effluent that can then be bio-treated in a local municipal wastewater treatment unit.

The composition of industrial effluents generated by the Move 4earth® demonstrator has been analyzed during several trials including a 48H test run at full speed in September 2018. Results were fully compliant with the limits in force.

A preliminary LCA conducted by Solvay experts in 2014 (from cradle to gate) revealed the very significant potential of the Move 4earth® technology when it comes to reducing environmental impacts for such criteria as CO₂ footprint, nonrenewable energy consumption, human health, ecosystems and water uptake. The study was comparing 35% glass fiber reinforced compounds, either made with recycled polymer produced using the Move 4earth® technology, or with virgin Polyamide 66 polymer. The results are depicted in the figure below.

Then, through a collaboration between SOLVAY, PSA and SOGEFI, a complete LCA study has been conducted on the scope of an automotive fuel filter housing including its usage phase during 150,000 km.
This analysis confirmed again the very significant benefits provided by Technyl® 4earth® recycled compounds: the impact reductions over the entire life cycle of this automotive component range from -10% to -40%. They are mainly due to the material production stage and result from the low impacts of the Move 4earth® recycling process.

The full report is available for download from the Move 4earth® web page:

More details about the direct environmental benefits of the projects are given in the coming section.
4. PROJECT ENVIRONMENTAL BENEFITS AND NEXT STEPS

4.1 Environmental Benefits

During its life time, the project has had significant direct impacts in Europe thanks to the utilization of more than 1500 tons of recycled polymer instead of virgin PA66 polymer to produce Polyamide 66 engineering compounds:

- More than 3000 tons of CO₂ emissions have been avoided.
- More than 36400 m³ of water and 113.850.000 MJ of primary energy have been saved.

Based on average annual CO₂ emissions and energy consumptions of European citizens in 2016, we can provide a more concrete estimate of the benefits achieved during the project as follows:

- A CO₂ reduction corresponding to the equivalent emissions of 427 European citizens in 2016.
- Energy savings corresponding to the equivalent consumption of 978 European citizens in 2016.

4.2 Next steps

To ensure the long-term benefits of the project, it is the intention of the project partners to pursue the following main actions after the end of the project:

- Monitor car dismantling networks and collaborate with partners to set up post-consumer airbags recycling streams.
- Launch Design for Recycling projects and expand the scope of the Move 4earth® technology to new technical textiles applications.
- Identify new applications for the silicone residues aiming for 100% material recovery.
- Further optimize the industrial performances and cost competitiveness of the technology preparing for future scale-up investments.
- Explore technology licensing opportunities when relevant.

To support all the above-mentioned initiatives, the project has also highlighted that it will of major importance that some regulations would evolve. The project has addressed the following recommendations to the EC:

- Amend the End of Life Vehicles directive to encourage the dismantlers extracting the front airbags and make them available for a logistic platform.
- Create a new legislation offering positive financial incentives for companies increasing their consumptions of high-quality recycled polyamide plastics.
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