LIFE CYCLE ASSESSMENT REPORT

TECHNYL 4EARTH®

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Supported by European Commission Life+ program.

LCA's approach and methodology critically reviewed by PwC.

Comparative Life Cycle Assessment
of two polyamide 66-based engineering plastic formulations,
one with a primary resin base, and the other with a high-quality recycled resin base (Technyl® 4earth®)

INTRODUCTION

Material recycling is one way to conserve resources and an essential component of the circular economy.

However, a certain number of imperatives and constraints must be respected during implementation:

FROM A TECHNICAL POINT OF VIEW, recycled materials should have similar performance characteristics to primary materials. This constraint depends of course on the intended application, but the more closely the quality of the recycled material matches that of the primary material, the more flexible the recycled material will be in terms of use.

FROM A SUSTAINABILITY POINT OF VIEW, the processes used in obtaining the recycled material must have less impact than the processes used to obtain the primary material.

FROM A REGULATORY POINT OF VIEW, recycled materials must meet the requirements of current regulations, such as REACH in Europe.

Solvay Performance Polyamides has developed the *'Move 4earth®'* technology which makes it possible to obtain a **high quality recycled polyamide 6.6 from airbag fabric scrap cuttings**. This production scrap consists of polyamide 6.6 woven yarn and a silicone coating, which gives the fabric the performance characteristics required to ensure that airbags function safely.

By using an innovative separation technique to remove this coating, the Move 4earth® recycling process enables the recovery of a very high quality polyamide 6.6 polymer, which can then be used as a matrix in the *Technyl® 4earth®* high-performance recycled engineering plastics range.

Using the Life Cycle Assessment methodology, this document aims to demonstrate that the Move 4earth® recycling process generates substantially lower potential environmental impacts than the processes for obtaining virgin polyamide 6.6 from primary materials.

The intent is thus to compare the potential environmental impacts resulting from the production of two formulations:

- Solvay Performance Polyamides's **Technyl® A218 V30 Black 21NS**, made from primary polyamide 6.6 produced by Solvay Performance Polyamides's traditional production lines,
- Solvay Performance Polyamides's **Technyl® 4earth® A4E 218 V35 Black** made from recycled polyamide 6.6 produced by Solvay Performance Polyamides using the Move 4earth® process.

The study was conducted in accordance with **ISO standards 14044.** Based on the principles of this standard, PricewaterhouseCoopers Advisory (PwC) critically reviewed Solvay Performance Polyamides' assumptions, used approach and methodology through the issuance of a report dated 3 July 2017 (see 'Conclusions' part for details on PwC scope & process). Solvay Performance Polyamides (i) had evaluated the adequacy and results of the services performed by PwC and (ii) made all decisions in connection with the services and PwC's recommendations.

The results of the study showed that, when used to manufacture an **automobile diesel fuel filter housing**, the recycled polyamide 6.6 formulation resulted in very significantly reduced potential impacts throughout the part's life cycle.

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1. GOAL AND SCOPE OF THE STUDY

The goal of the study is to establish and publish tangible evidence regarding the reduction of potential environmental impacts by substituting a partially recycled material for a primary material during the production of an automotive part.

Cradle-to-gate study quantifying environmental impact reduction

Specifically, this study aims to quantify the reduction in potential environmental impacts resulting from replacing a glass fiber-reinforced polyamide formulation produced by Solvay Performance Polyamides by another glass fiber-reinforced polyamide formulation, also produced by Solvay Performance Polyamides, made with a polyamide matrix (polyamide 6.6) produced from airbag production fabric scrap cuttings via an original recycling process.

Figure 1: diesel fuel filter housing FC 615 by SOGEFI

The study reported herein and conducted by Solvay Performance Polyamides is thus a **comparison** of the production-related potential environmental impacts (from **cradle-to-gate**) of the two formulations:

- Solvay Performance Polyamides's **Technyl® A218 V30 Black 21NS**, made from primary polyamide 6.6 produced by Solvay Performance Polyamides's traditional production lines,
- Solvay Performance Polyamides's **Technyl® 4earth® A4E 218 V35 Black** made from recycled polyamide 6.6 produced by Solvay Performance Polyamides using the Move 4earth® process.

The study first considered the production of 1 kg of each formulation and then looked at the manufacture and life cycle of a diesel fuel filter housing (SOGEFI FC 615).

The design of the housing was identical for the two formulations but their densities differing somewhat, the following masses were considered:

- **196 grams** with the formulation **Technyl® A218 V30 Black 21NS**,
- **203 grams** with the formulation **Technyl® 4earth® A4E 218 V35 Black**

↳ The production of the two formulations includes the following steps:

For the formulation based on **primary polyamide 6.6:**

- Extraction of raw materials for the materials (polyamide 6.6 intermediates, additives, reinforcement) and energy production for the entire process;
- Production of intermediates and ingredients;
- Polymerization of polyamide 6.6;
- "Compounding" of the formulation's ingredients.

For the formulation based on **recycled polyamide 6.6:**

- Extraction of raw materials for the materials (additives and reinforcement) and energy production for the entire process;
- Production of intermediates and ingredients;
- Recycling of the polyamide 6.6 (i.e. separation of the polyamide 6.6 from its coating, and compacting);
- "Compounding" of the formulation's ingredients.

↳ Details of the two systems boundaries are shown in Figure 2 below:

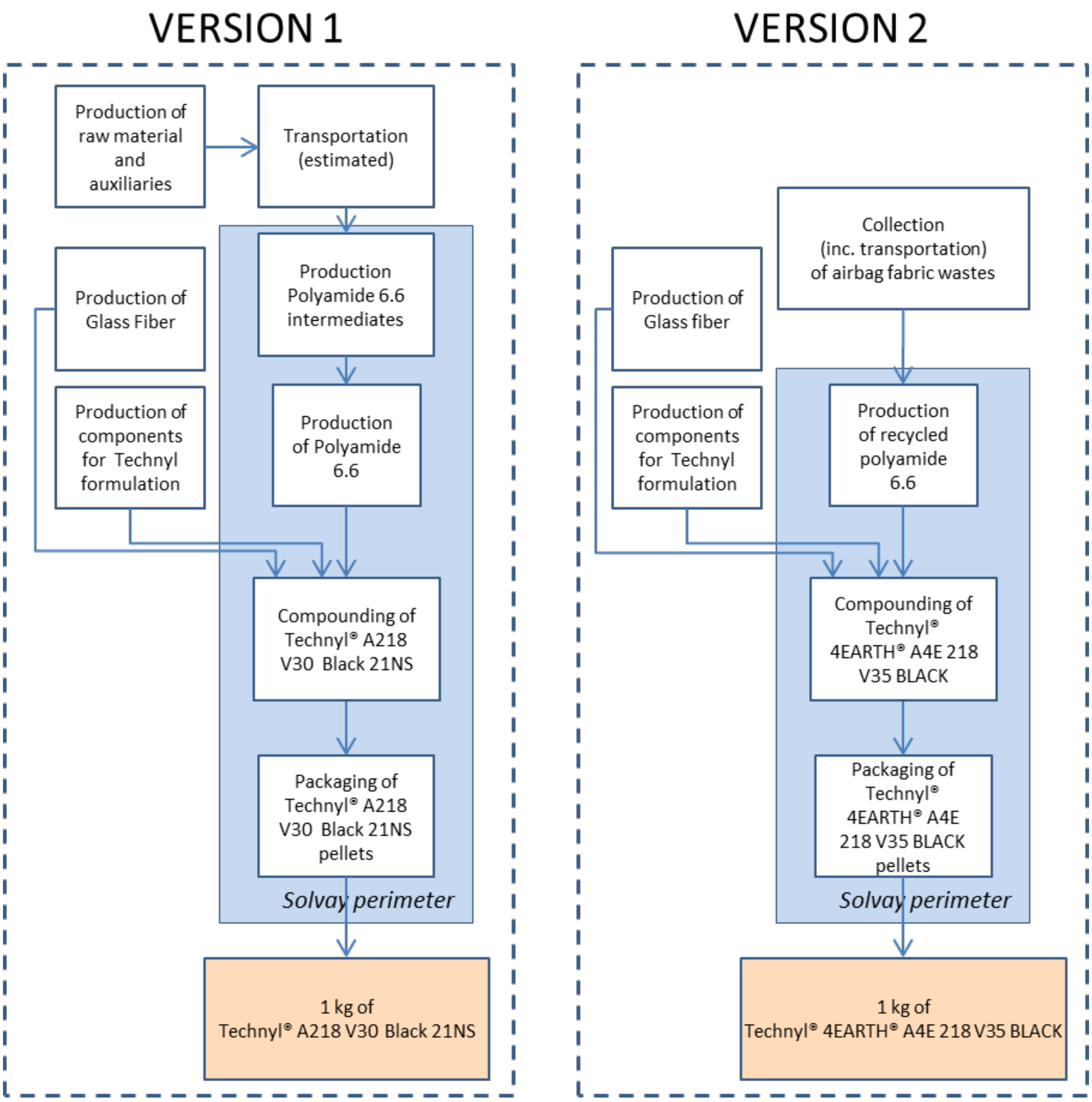

Figure 2: Schematic representation of the compared systems boundaries, after simplification.

MAIN METHODOLOGICAL CHOICES AND ASSUMPTIONS

1. SIMAPRO software v8.1.1.16.
2. Background data: ecoinvent v2.2.
3. Model for the glass fiber: based on "Life Cycle Assessment of CFGF – Continuous Filament Glass Fibre Products – February 2012", prepared by PwC for Glass fiber Europe, ELCD data in SIMAPRO.
4. Primary data for operations within Solvay Performance Polyamides's perimeter (primary polyamide 6.6 and its intermediates, recycled polyamide, compounding, etc.).
5. Airbag fabric scrap cuttings enter the system burdenless, the system boundaries include their collection and delivery to the Solvay Performance Polyamides site.
6. Infrastructure processes were omitted.

2. POTENTIAL ENVIRONMENTAL IMPACTS

related to the production of 1 kg of each of the two glass fiber-reinforced polyamide 6.6 formulations.

Potential environmental impacts were assessed using six indicators covering a wide range of impact categories relevant to this case study:

- **Greenhouse Gas** (GHG) **emissions** (IPCC 2013 100y)
- **Cumulative Energy Demand** (CED v1.08)
- **Acidification** (ILCD 2011 midpoint)
- **Eutrophication** (CML IA v4.2 2013)
- **Photochemical Ozone Formation** (ILCD 2011 midpoint)
- **Water withdrawals** (sum of all withdrawals, assessing water requirements)

The first five indicators were used as available in SIMAPRO v8.1.1.16.

Note:

Since the Move 4earth® recycling process results in savings of an organic material (i.e. polymer), the savings in fossil resources arising from such recycling were accounted for via the CED (Cumulative Energy Demand) indicator, which aggregates all fossil fuel inputs required by the process, for both energy and the material.

↳ Results are as follows:

Move 4earth® process reduces environmental impacts by 30 to 70%

The process of recycling airbag fabric scrap cuttings into polyamide 6.6 for engineering plastic formulations – due to its simplicity – proved to be environmentally preferable to the traditional process used to obtain primary polyamide 6.6. This process simultaneously saves raw materials, by reusing production scrap, and reduces all potential environmental impacts considered (representing a wide range of impact categories) by 30% to 70% *(cf. Table 1 below)*.

It would appear that it is the change in pathway (primary to recycling) for the polyamide matrix that is responsible for the potential impacts reduction between the two formulations *(cf. Figure 2 below)*.

Technyl® A218 V30 Black 21NS and Technyl® 4earth® A4E 218 V35 Black

Impact category (for the production of 1 kg of formulation)	*Unit*	**Technyl® A218 V30 Black 21NS**	**Technyl® 4EARTH® A4E 218 V35 Black**	Relative environmental benefits of Technyl 4E vs. Standard Technyl
GHG emissions (Greenhouse Gas)	*kg CO_2 eq.*	**4,4**	**3,0**	**-32%**
CED (Cumulative Energy Demand)	*primary MJ*	**97**	**44**	**-54%**
Acidification	*molc H^+ eq.*	**1,0E-02**	**6,2E-03**	**-40%**
Eutrophication	*kg PO_4^{--} eq.*	**2,8E-03**	**9,4E-04**	**-66%**
Photochemical ozone formation	*kg NMVOC eq*	**8,9E-03**	**5,7E-03**	**-36%**
Water withdrawals	*m^3*	**2,0E-01**	**5,8E-02**	**-71%**

Table 1: Potential environmental impacts results related to the production of 1 kg of each glass fiber-reinforced polyamide 6.6 formulation,

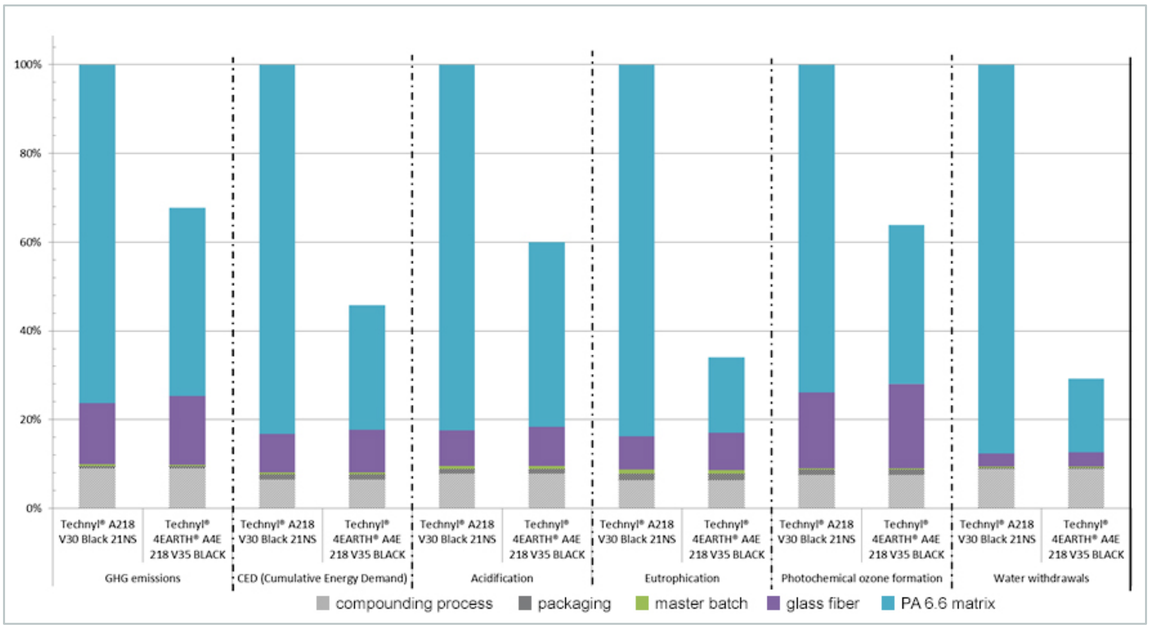

Figure 2: Contributions to potential environmental impacts of the various ingredients, compounding process and packaging of the finished product for both formulations.

The slight variation in glass fiber content between the two formulations (30% for Technyl® A218 V30 Black 21NS and 35% for Technyl® 4earth® A4E 218 V35 Black) had a minimal effect on the differences observed between the two formulations.

It should be noted that the reduction in water withdrawals is to a rather high degree uncertain due to the poor quality of the water use inventories available in the databases used for background data (regarding certain primary-process raw materials sourced outside of Solvay Performance Polyamides).

However, there is a real and very important reduction in water withdrawals between the primary and recycling in-house processes, for which Solvay Performance Polyamides has very accurate records.

Comment on the decision to consider airbag fabric scrap cuttings entering the system as burdenless:
A sensitivity analysis was done considering an economic allocation of the burdens of the airbag element manufacturing process between the cut airbag element and the fabric scrap cuttings generated. It showed the same orders of magnitude of potential impacts reduction for the recycled polyamide while the airbag element is experiencing a small reduction of its own potential environmental impacts (i.e. a reduction of around 1.5%).

The previous results, which were critically reviewed by *PwC*, were used to compare the life cycle potential impacts of an automotive part – a diesel fuel filter housing (SOGEFI FC 615) – manufactured on the one hand, using the Technyl® A218 V30 Black 21NS formulation, and on the other hand, using the Technyl® 4earth® A4E 218 V35 Black formulation. The mass used for each formulation differs according to their respective densities *(cf. part 2)*.

The following steps were considered in this comparison:

- **Production of the formulations** by Solvay Performance Polyamides *(results presented in Table 1)*.
- **Transport of the material** from the Solvay Performance Polyamides site to the SOGEFI site.
- **Production of the part** by SOGEFI.
- **Transport of the part** from the SOGEFI site to the PSA PEUGEOT CITROEN site where the vehicle is assembled.
- **Use** (transport of the part over the service life of the vehicle, i.e. 150,000 km).
- **End of life of the part**.

Note:

For this part of the study considering the life cycle stages downstream of the production of the material, the water withdrawals indicator is not presented since water requirements data was not available for those stages. Nevertheless, to our knowledge there are no data implying any variation for this indicator between the two housing versions.

↳ The main assumptions are as follows:

The use stage is modeled solely through the fuel consumption required to transport the part and the associated combustion emissions, with the following assumptions (*according to Koffler, Christoph, and Klaus Rohde-Brandenburger. 2010. "On the Calculation of Fuel Savings through Lightweight Design in Automotive Life Cycle Assessments." IJLCA 15 (1)*):

- Fuel consumption (Diesel) related to the mass transported:
  - → 0.12 liters of diesel per 100km per 100kg
- Emissions:
  - → CO_2: 3.12 kg of CO_2 per kg of fuel
  - → SO_2: 3.5 x 10^{-4} kg SO_2 per kg of fuel

End of life: incineration without energy recovery.

↳ Results are as follows:

Regardless of the impact indicator, the material production and use stages are the principal contributors, with the other stages (material transport, housing manufacture and end-of-life) having small to negligible contributions.

Non-material production-related contributions do not vary significantly between the two versions of the part.

Thus **the impact reductions over the entire life cycle of the housing (which range from about 10% to 40%) are mainly due to the material production stage and result from the low potential impacts of the Move 4earth® recycling process** *(cf. Figure 3).*

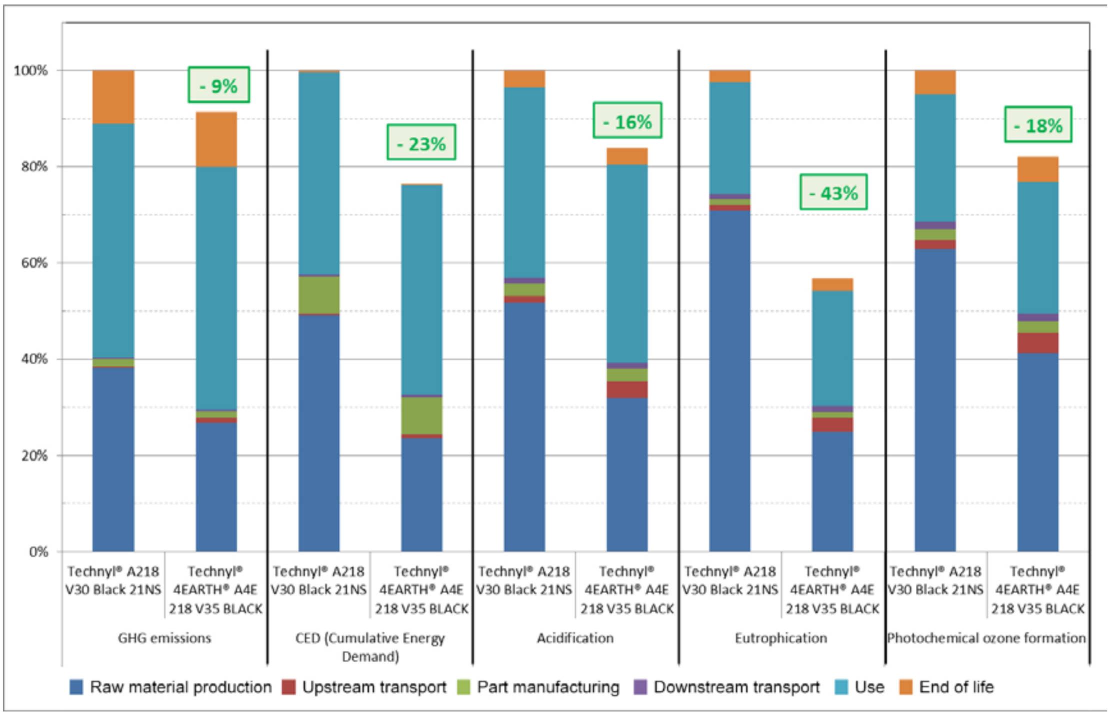

Figure 3: Contributions to potential environmental impacts of the various life cycle stages for the diesel fuel filter housing.

SOGEFI tests confirmed the similar performance of the 2 materials

It is also important to note that tests carried out by SOGEFI have confirmed that the functional performance (including service life) of a diesel fuel filter housing manufactured with Technyl® 4earth® recycled material was identical to that of a housing made from traditional Technyl® material.

4. CONCLUSIONS

From cradle-to-gate, Technyl® 4earth® reduces environmental impact from 30 to 70% depending on the indicator considered

The production of the engineering plastics in the **Technyl® 4earth® range generates significant reductions in potential environmental impacts** compared to equivalent materials made from a primary polyamide 6.6 matrix, via traditional processes.

In the case of a 35% glass fiber reinforced grade and according to the assumptions presented herein, those reductions are of the order of **-30% to -70%** depending on the impact indicator considered.

The use of Technyl® 4earth® materials to manufacture injection-molded plastic parts significantly reduces their environmental footprint.

In the case of a 35% glass fiber reinforced grade used to manufacture an automotive diesel fuel filter housing and according to the assumptions presented herein, the potential impact reductions over its entire life cycle are of the order of **-10% to -40%** depending on the impact indicator considered.

Technyl® 4earth® significantly reduces environmental footprint of injection-molded parts

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Solvay Performance Polyamides is the global specialist in polyamide-based engineering plastics, with more than 60 years of experience in the development, manufacture and marketing of a complete range of high-performance materials under the Technyl® brand for demanding applications in automotive, consumer goods and electrical markets. With a growth strategy bolstered by fourteen production sites worldwide, the Global Business Unit employs its expertise and innovation capabilities in order to serve the needs of its customers more closely through a global network of technical and R&D centers.

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