PolyCE

Post-Consumer High-tech Recycled Polymers for a Circular Economy

Project Duration: **01/06/2017 - 31/05/2021**

Deliverable No.: **1.4**

Deliverable Title: Matrix of industrial symbiosis opportunities

Version Number: I

Due Date for Deliverable: **31/01/2020**

Actual Submission date: **27/01/2020**

Lead Beneficiary: UGent

Lead Author: Andrea La Gala

Deliverable Type: R

R = Document, report
DEM = Demonstrator, pilot, prototype, plan designs
DEC = Websites, patent filing, press & media actions, videos, etc.

Dissemination Level: PU

PU = Public
CO = Confidential, only for members of the consortium, including the Commission Services

Lead Author Contact: Andrea La Gala

CPMT

Phone: +32.0483161768
e-mail: Andrea.lagala@ugent.be

Contributing Partners

List partners and / or co-authors contributing to this Deliverable

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730308

Summary

With the global plastic production expected to grow to 460 million of tons per year by 2030[30] and the EEE sector being the fourth largest for global plastic demand, it is crucial to introduce a circular model to preserve the natural resources and the environment.

While the PolyCE focuses on closing the plastic loop for electronic equipment applications, the Task 1.6 evaluated the possibility to open this loop on the 'intake' side and to consider the use of PCR plastics from a different origin than WEEE, laying the foundations for possible symbiosis between EEE and the other relevant sectors.

To fully understand the potential of a symbiosis between these different sectors, the opposite scenario was also considered, with examples of application for EEE wastes in different sectors. These applications are presented in Table I and Table II with the scope to provide examples of possible synergies between EEE and other relevant sectors.

It appeared clear that the materials and the industrial processes used in EEE and the other sectors are in many cases comparable and, even without a full characterization for the sources, it is evident that these materials can still be valuable for new applications in different sectors.

In many cases though, it is either not possible or not profitable not to effectively separate each different polymer from the current heterogenous plastic mix mostly made from shredded residues. Solutions to this problem, that include alternative sorting methods are being evaluated within the PolyCE initiatives.

In conclusion, the synergies between different sectors can indeed represent an important step towards plastic sustainability, but in order to establish the feasibility of the various industrial synergies, and evaluate more specific applications, an in-depth characterization of the different sources is crucial.

Inhalt

1 Introduction

In 2018, the global plastics production almost reached 360 million of tons[29], while the global plastic demand is expected to grow to 460 million of tons per year by 2030[30].
It is apparent that the linear economy model (make, use, dispose), commonly used in the plastics industry should be replaced by a circular model where products and materials are at the end of each service life.
While the PolyCE project focuses on closing the loop for PCR polymers in electronic equipment applications, the scope of Task 1.6 is to evaluate symbiosis opportunities between WEEE and other relevant sectors.
The 6 most used polymers in Electrical and Electronic Equipment[12,21] have been investigated and different examples of possible synergies between EEE and other sectors were provided in two tables.
The first table includes examples of sources of PI and PCR plastics that can be included in the EEE loop, while the second table includes examples for the opposite scenario, where materials from WEEE can be used for new applications in different sectors.
It is worthwhile to mention that at the actual state it is often problematic to effectively separate the different polymers from the heterogenous plastic mix.
The material coming from many recycling sources can be in fact a mix of different polymers (plastics, rubber, foams), and can includes metal oxides, glass, and dirt, as well as residual amounts of ferrous and nonferrous metals.
On the other hand, one of the objectives of the PolyCE project is to establish new approaches to plastic sorting and recycling, to prove that is possible to reach the desired plastic quality.
It is also important to remember that the document is meant to be purely informative and, given the many possible applications, it shouldn't constitute in any way a limit for the reader.

1.1 Object of the investigation

The investigation focused on the 6 most used polymers in Electrical and Electronic Equipment[12,21] (EEE). These polymers are, from the most to the least used:

I. ABS (Acrylonitrile-Butadiene-Styrene)

Acrylonitrile-Butadiene-Styrene (ABS) is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene cross-crossed with shorter chains of poly(styrene-co-acrylonitrile).
ABS is the preferred engineering plastic when it comes to dealing with automotive applications, but is also used for House appliances, Electrical & Electronics Applications, 3D printing.

II. HIPS (High Impact Polystyrene)

High Impact Polystyrene (HIPS) is a form of polystyrene (PS) that carries with it a higher impact strength. Homopolymer PS can often be brittle and can be made more impact resistant if combined with other materials. This form of PS typically is produced by adding around 5-10% rubber or butadiene copolymer. This increases the toughness and impact strength of the polymer.
HIPS is mainly used for packaging materials, such as food, cosmetics, daily necessities, machinery and instruments and stationery packaging; can be molded using a variety of processing methods.

III. PP (Polypropylene)

Polypropylene (PP) is a thermoplastic polymer used in a wide variety of applications. It is produced via chain-growth polymerization from the monomer propylene. Polypropylene belongs to the group of polyolefin and is partially crystalline and non-polar. Its properties are similar to polyethylene, but it is slightly harder and more heat resistant. It is a white, mechanically rugged material and has a high chemical resistance.[1] Polypropylene is the second-most widely produced commodity plastic (after polyethylene) and it is often used in packaging and labelling.

IV. PC/ABS (Polycarbonate/ Acrylonitrile-Butadiene-Styrene)

Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) is a blend of PC and ABS providing unique combination of the high processability of ABS with the excellent mechanical properties, impact and heat resistance of PC.
The PC/ABS property balance is controlled by the ratio of PC and ABS in the blend, the polycarbonate molecular weight and the additive package. The ratio of polycarbonate and acrylonitrile-butadiene-styrene affects mainly the heat resistance of the final product. PC/ABS blends exhibit a synergic effect resulting in excellent impact resistance at low temperatures that is better than impact resistance of ABS or PC.
Typical applications of PC/ABS blends are Automotive, especially for paneling, Electronics and 3DPriting.

V. PE (Polyethylene)

Polyethylene (PE) is a light, versatile synthetic resin made from the polymerization of ethylene.
PE is the most common plastic, its primary use is in packaging (plastic bags, plastic films, geomembranes, containers including bottles, etc.).

VI. PC (Polycarbonate)

Polycarbonate (PC) plastics are a naturally transparent amorphous thermoplastics commonly used for plastic lenses in eyewear, in medical devices, automotive components, protective gear, greenhouses, Digital Disks, and exterior lighting fixtures.

Polycarbonate has very good heat resistance and can be combined with flame retardant materials without significant material degradation.

2 Opening the EEE loop

The first part of the investigation, whose results are presented in Table I, focused on the plastics from a different origin than WEEE, evaluating their integration in the recycling loop for EEE. The investigation was not limited to Post-Consumer Recycled plastic as originally intended, but to provide a more exhaustive scheme it was extended to some Post-Industrial applications.

2.1 The streams organization

The different streams have been organized by material, providing a detailed information for each specific stream.

I. **Sector**

Identifies the general sector.
For better clarity, the packaging sector was divided into 3 different categories:
PTTs (pots, tubes and trays), **Bottle/Flask, Films.**
A more detailed description of those categories will be provided later in the report.

II. **Origin**

The materials are divided into Post-Industrial (PI) and Post-Consumer (PC).

III. **Source**

Identifies the application of the material in the sector or, where applicable, the source of the wastes.

IV. **Processability**

Indicates, where applicable, the suitability of the materials for processing.
The indications of processability are based on the values of MFR available for some of the sources. Where a complete characterization of the material was not available, an expected indication of the processability was given.
A more detailed characterization for some of the sources will take place in Task 7.9 - “Validation of PCR plastics from non-WEEE streams in new EE applications”.

V. **Waste generated (EU) [Mt/y]**

Indicates the amount of waste generated in Europe, indicated in millions of tons per year.

VI. **Availability in the application**

Indicates the share of the specific material used in the sector or the specific application.

As a conceptually relevant connection to Task 7.8 -“3D printing technology optimized for PCR plastics from WEEE” it deems appropriate mentioning also the 3D printing wastes as an additional stream but given the limited amounts available this was omitted from the main table.

It is still worth to consider the 3D printing application as a relevant option for recycle waste materials from WEEE for both the recycling of the materials for new parts and demonstrators within EEE and the recycling of the materials outside EEE.

2.2 The streams organization

The different streams have been organized by material, providing a detailed information for each specific stream.

I. **Sector**

Identifies the general sector.

For better clarity, the packaging sector was divided into 3 different categories:

PTTs (pots, tubes and trays), **Bottle/Flask, Films.**

A more detailed description of those categories will be provided later in the report.

II. **Origin**

The materials are divided into Post-Industrial (PI) and Post-Consumer (PC).

III. **Source**

Identifies the application of the material in the sector or, where applicable, the source of the wastes.

IV. **Processability**

Indicates, where applicable, the suitability of the materials for processing.

The indications of processability are based on the values of MFR available for some of the sources. Where a complete characterization of the material was not available, an expected indication of the processability was given.

A more detailed characterization for some of the sources will take place in Task 7.9 - "Validation of PCR plastics from non-WEEE streams in new EE applications".

V. **Waste generated (EU) [Mt/y]**

Indicates the amount of waste generated in Europe, indicated in millions of tons per year.

VI. **Availability in the application**

Indicates the share of the specific material used in the sector or the specific application.

As a conceptually relevant connection to Task 7.8 -"3D printing technology optimized for PCR plastics from WEEE" it deems appropriate mentioning also the 3D printing wastes as an additional stream but given the limited amounts available this was omitted from the main table.

It is still worth to consider the 3D printing application as a relevant option for recycle waste materials from WEEE for both the recycling of the materials for new parts and demonstrators within EEE and the recycling of the materials outside EEE.

2.3 Categories and sectors

Automotive: The automotive sector comprises a wide range of companies and organizations involved in the design, development, manufacturing, marketing, and selling of motor vehicles. It is one of the world's largest economic sectors by revenue and the third by plastic volume demand [11].

Bottle/Flask: This category includes all kind of packaging considered as "hollow bodies" such as packaging for drinks (water, milk, juices, sauces, etc.), cleaning products (detergents, chemicals, etc.) or hygiene (shampoos, shower gels, etc.). Some bottles, especially for gaseous drinks are made with multilayers of plastics for a more effective maintenance of carbon dioxide.

Construction: This category includes buildings, infrastructure and industrial sectors. It is the second largest sector by plastic volume demand [11].

ELVs: An end-of-life vehicle is a vehicle that is no longer usable. It may be a car or van at the end of its life. These vehicles are no longer usable and can contain toxic elements classified as dangerous waste[12].

Films: This category includes all flexible packaging (mainly multilayer, such as bags (garbage bag, shopping bag, bulk bag, boil-in bag, etc.), complex films (stand up pouch bag for juice, stewed fruits, sugar, detergents, etc.), foils (pellets films, labels, etc.).

PTTs (pots, tubes and trays): This category includes all rigid packaging excluding bottles and flasks. Specifically, it includes pots (yogurts, cosmetic creams, etc.), trays (fruits, vegetables, ready prepared dishes, clamshells containers or consumer goods, etc.), other flat packaging (such as blister pack for unit-dose pharmaceuticals, etc.) and tubes (toothpaste, glue, paints, etc.). In this category, multilayer packaging is also found, especially for trays and containers used in food-contact applications. It also includes industrial canisters and containers (when industrial packaging is concerned).

Sport Goods: Includes sport equipment.

2.4 Matrix of industrial symbiosis opportunities - From other sectors to EEE

TAB I	Sector	Origin	Source	Processability [27]	Waste Generated (EU) [Mt/y]	Availability within the application
ABS	ELVs	PC	Shredded residue from separation process [15]	TBE[3,4,6]	0,18[2,28]	0,45-1,56% in weight of a vehicle[2,15,26]
ABS	Automotive	PI	Production waste	Expected to be good[20]	-	n/a
HIPS	ELVs	PC	Shredded residue from separation process [15]	TBE[3,4,6]	0,42[2,28]	0,15-0,54% in weight of a vehicle[2,15,26]
HIPS	Automotive	PI	Production waste	Expected to be good[20]	-	n/a
PP	ELVs	PC	Shredded residue from separation process [15]	TBE[3,4,6]	0,42[2,28]	1,5% to 3% in weight of a vehicle[2,15,26]
PP	Automotive	PI	Production waste	Expected to be good[20]	-	n/a
PP	Bottle/Flask (HHW)	PC	PC separated waste and mixed waste[5]	TBE[5]	0,06[13]	Variable
PP	PTTs (HHW)	PC	PC separated waste and mixed waste[5]	TBE[6]	1,86[13]	Variable
PP	Films (HHW)	PC	PC separated waste and mixed waste[5]	TBE[6]	0,54[13]	Variable
PP	Bottle/Flask (CI)	PI	Commercial and Industrial waste[13]	Expected to be good[5]	0,26[13]	Variable
PP	PTTs (CI)	PI	Commercial and Industrial waste[13]	Expected to be good[6]	2,17[13]	Up to 100% of the product
PP	Films (CI)	PI	Commercial and Industrial waste[13]	Expected to be good[6]	0,84[13]	Variable
PP	Sport Goods	PI	Production waste ski boots	Good[19]	-	25-88% of the product[7]
PC/ABS	ELVs	PC	Shredded residue from separation process [15]	TBE[3,4,6]	0,02[2,28]	0,06-0,14% in weight of a vehicle[2,15,26]
PC/ABS	Automotive	PI	Shredded residue from separation process [15]	TBE[3,4,6]	-	
HDPE	ELVs	PC	Shredded residue from separation process [15]	TBE[3,4,6]	0,32[2,28]	1 to 2,2 % in weight of a vehicle[2,15,26]
HDPE	Automotive	PI	Production waste	Expected to be good	-	n/a
HDPE	Bottle/Flask (HHW)	PC	PC separated waste and mixed waste[5]	TBE[5]	1,04[13]	Variable
HDPE	PTTs (HHW)	PC	PC separated waste and mixed waste[5]	TBE[6]	0,35[13]	Variable
HDPE	Films (HHW)	PC	PC separated waste and mixed waste[5]	TBE[6]	0,35[13]	Variable
HDPE	Bottle/Flask (CI)	PI	Commercial and Industrial waste[13]	Expected to be good[5]	4,56[13]	Variable
HDPE	PTTs (CI)	PI	Commercial and Industrial waste[13]	Expected to be good[6]	1,70[13]	Up to 100% of the product
HDPE	Sport Goods	PI	Production waste ski boots	Good[19]	-	25-88% of the product[7]
PC	Construction	PC	Shredded residue from PC panels	TBE in 7.9	-	Variable

PTTs includes Pots, tubes and trays, **Bottle/Flask** includes all "hollow bodies", **Films** includes all flexible packaging, complex films, foils. **CI=**Commercial and Industrial **PI=**Post-Industrial, **PC=**Post-Consumer**, HHW**=Household Waste, **CI**=Commercial & Industrial waste, **TBE**=To Be Evaluated

2.5 Compendium

MFI (Melt Flow Index)

The Melt Flow Index (MFI) is a measure of the ease of flow of the melt of a thermoplastic polymer. It is defined as the mass of polymer, in grams, flowing in ten minutes through a capillary of a specific diameter and length by a pressure applied via prescribed alternative gravimetric weights for alternative prescribed temperatures.
The optimal ranges for the technological processes mentioned are[6,21]:

Process	Optimal MFI Range[6,21]
Extrusion	~0 - 1
Blow Molding	0.3 - 5
Injection molding	5 - …
3DPrinting[22]	1 - 10[22]

Matrix of processability

End of life vehicles

End of life vehicles were identified as one of the primary streams to be integrated into the recycling loop of WEEE due to similarities in the waste composition. After some investigations with the partners directly involved into vehicles recycling and sorting, some doubts were raised about the suitability of the material to be recycled for EEE applications. Therefore, while the ELVs will be kept as a primary PCR plastic stream for the deliverable 1.4, an in-depth investigation and a characterization will be carried on in Task 7.9 - “Validation of PCR plastics from non-WEEE streams in new EE applications”

PCR Polycarbonate

A Polycarbonate PCR source is also included among the materials to be evaluated for the WEEE recycling loop integration. Given the interest of some of the partners, the material will be further characterized within Task 7.9- “Validation of PCR plastics from non-WEEE streams in new EE applications” and its suitability for application in the Deliverable D7.5 - “Philips PCR plastics demonstrator, M40

3 From EEE to other relevant sectors

Demand. Within those applications was also evaluated the possibility, mainly for PE, PP and PS to foam the polymer for packaging applications.
Due to the strict regulations for unknown sources materials however, food packaging applications were not considered.

3.1 The streams organization

The different applications have been sorted by material, providing a detailed information for each specific application:

I. **Sector**
Identifies the general sector.

II. **Application**
Identifies the application of the material in the sector.

III. **Amount of material used in the sector per year (EU) [Mt/y]**
Indicates the amount of the specific used in the specific application material per year.

IV. **Percentage of recycled material used in blend [%]**
Indicate the amount of recycled material currently used in the application.

V. **Availability within the application**
Indicates the share of material used in the sector or the specific application

VI. **Processing Method**
Indicates the industrial process commonly used for production

3.2 Categories and sectors

Automotive: The automotive sector comprises a wide range of companies and organizations involved in the design, development, manufacturing, marketing, and selling of motor vehicles. It is one of the world's largest economic sectors by revenue and the third by plastic volume demand[11].

Construction: This category includes buildings, infrastructure and industrial sectors. It is the second largest sector by plastic volume demand [11].

Packaging: The packaging sector is the largest sector for plastic volume demand, and represents about the 40% of the global plastic demand [11].

Furniture: Includes the movable articles, as tables, chairs, desks or cabinets, required for use or ornament in a house, office, or public areas.

Sport Goods: Includes sport equipment.

3.3 Matrix of industrial symbiosis opportunities - From EEE to other sectors

TAB II	Sector	Application	Amount of material used in the sector per year (EU) [Mt/y]	Percentage of recycled material used in blend [%]	Availability within the application	Processing Method
ABS	Automotive	Bumpers, seating, trim, lighting, etc. [1]	0,31[13,15,26]	Up to 40%[23,24]	0,45-1,56% in weight of a vehicle[2,15,26]	IM
HIPS	Automotive	Bumpers, panels, tanks, etc.[1, 16]	0.11[13,15,26]	Up to 40%[23,24]	0,15-0,54% in weight of a vehicle[2,15,26]	IM, EBM
HIPS	Furnitures	Decking, boards, sheets, outdoor furniture.	n.a.[27]	100%[9]	Variable (mixed plastics)	E
HIPS	Packaging	Foils, Expanded PS, etc.	n.a.[27]	-	Variable	E
PP	Automotive	Bumpers, tanks, panels, trim, etc.[1]	0,12[13,15,26]	Up to 40%[23,24]	1,5% to 3% in weight of a vehicle[2,15,26]	IM, EBM
PP	Furnitures	Decking, boards, sheets, outdoor furniture.	-	100%[9]	Variable (mixed plastics)	E
PP	Packaging	Foils, Expanded PP, etc.	5,61[13]	-	Variable	E
PP	Construction	Composites	n.a.[27]	Up to 55%[8]	Up to 95 of the product%	E
PP	Sport Goods	Ski boots shell	n.a.[27]	Up to 30%[19]	25-88% of the product[7]	IM
PC/ABS	Automotive	Roof spoilers, grills, housings, roof bows.	0,028[13,15,26]	Up to 40%[23,24]	0,06-0,14% in weight of a vehicle[2,15,26]	IM
PC/ABS	Furnitures	Decking, boards, sheets, outdoor furniture.	n.a.[28]	100%[9]	Variable (mixed plastics)	E
PE	Automotive	Fuel tanks, liquid reservoirs. [1,14]	0,09[13,15,26]	Up to 40%[23,24]	1 to 2,2 % in weight of a vehicle[2,15,26]	IM, EBM
PE	Furnitures	Decking, boards, sheets, outdoor furniture.	n.a.[27]	100%[9]	Variable (mixed plastics)	E
PE	Packaging	Foils, expanded PE, etc.	6,91[13]	-	Variable	E
PE	Sport Goods	Ski boots shell	n.a.[27]	Up to 30%[19]	25-88% of the product[7]	IM

IM= Injection Moulding; **E**=Extrusion; **EBM**=Extrusion Blow Moulding;

4 Conclusions

Within Task 1.6 it was possible to identify many opportunities for industrial synergies between EEE and other relevant sectors.
It appeared clear that the materials and the processes used in EEE and the other sectors are in many cases equivalent and, even before a full characterization for the sources, it is possible to expect that these materials would still be valuable for new applications in different sectors.
It is worth to repeat though that, being in many cases either not possible or not profitable to effectively separate each different polymer from the shredded residues, it is essential to improve the quality of the current mix of materials.
Many initiatives for this purpose are already taking place, like the alternative clustering sorting methods that are being evaluated within the PolyCE project.
Finally, in order to effectively establish the feasibility of the proposed industrial synergies, and evaluate more specific applications, a deep characterization of the different sources is crucial.

5 Notes and References

1] Szeteiová, Katarína. "Automotive materials plastics in automotive today." (2010).
2] Sorema.it: Car plastic waste recycling, retrieved from: http://sorema.it/en_US/applications/other-recycling-solutions/car-plastic-waste-recycling/
3] M. P. Luda, V. Brunella, and D. Guaratto, "Characterisation of Used PP-Based Car Bumpers and Their Recycling Properties," ISRN Materials Science, vol. 2013, Article ID 531093, 12 pages, 2013. https://doi.org/10.1155/2013/531093
4] Luda, Maria & Ragosta, Giuseppe & Musto, Pellegrino & Acierno, Domenico & Di Maio, Luciano & Camino, Giovanni & Nepote, Valeriano. (2003). Regenerative Recycling of Automotive Polymer Components: Poly(propylene) Based Car Bumpers. Macromolecular Materials and Engineering. 288. 613 - 620. 10.1002/mame.200300001.
5] Dahlbo, H., et al. Recycling potential of post-consumer plastic packaging waste in Finland. Waste Management (2017), https://doi.org/10.1016/j.wasman.2017.10.033
6] M.K. Eriksena, J.D. Christiansenb, A.E. Daugaardc, T.F. Astrupa (2019): Closing the loop for PET, PE and PP waste from households: Influence of material properties and product design for plastic recycling, Waste Management Voume 95
7] Colonna, Martino & Nicotra, Marco & Matteo, Moncalero. (2013). Materials, Designs and Standards Used in Ski-Boots for Alpine Skiing. Sports. 1. 78-113. 10.3390/sports1040078.
8] Kazemi, Saeed & Kiaefar, Azadeh & Hamidina, Elham & Tajvidi, Mehdi. (2007). Water Absorption Behavior of Composites from Sawdust and Recycled Plastics. Journal of Reinforced Plastics and Composites - J REINF PLAST COMPOSITE. 26. 341-348. 10.1177/0731684407072519.

9] K. Recep, A. Özgür, Ç. Metinİpeka : "Properties of polypropylene fiber reinforced concrete using recycled aggregates" from Construction and Building Materials Volume 98, 15 November 2015, Pages 620-630
10] "End of Life Vehicles." End of Life Vehicles - Waste - Environment - European Commission, https://ec.europa.eu/environment/waste/elv/.
11] Müller - Guttenbrunn Group "Circular Economy ELV and WEEE Plastics - an Industry Wish List -"
http://www.newinnonet.eu/media/docs/WEEE_PCR_Plastics_and_Circular_Economy_Innonet_Conference_Brussels_June_8th.pdf
12]Futura-Sciences. "End-of-Life Vehicles." *Futura*, http://www.futura-sciences.us/dico/d/sustainable-development-end-life-vehicles-50000854/.
13] M. Hestin, A. Mitsios, S. Ait Said, F. Fouret, A. Berwald, V. Senlis (2009) "Blueprint for plastics packaging waste: Quality sorting & Recycling"
https://www.plasticsrecyclers.eu/sites/default/files/PRE_blueprint%20packaging%20waste_Final%20report%202017.pdf
14] Gu, Fu & Hall, Philip & Wu, Tao. (2012). The Recycling of Plastics from ELVs - Background, Practices and Potentials. Advanced Materials Research. 542-543. 271-280. 10.4028/www.scientific.net/AMR.542-543.271.
15] Sakai, S., Yoshida, H., Hiratsuka, J. et al. J Mater Cycles Waste Manag (2014) 16: 1. https://doi.org/10.1007/s10163-013-0173-2
16] "High Impact Polystyrene Thermoforming and Injection Molding - API." Advanced Plastiform, Inc., https://advancedplastiform.com/materials/hips/.
17] Eriksen, M. K. (2019). Quality and Recyclability of Plastic from Household Waste. Kgs. Lyngby: Technical University of Denmark.
18] Report, Staff. "MATERIALS: PC-ABS with a Density Advantage for Automotive." *Plastics Technology*, Plastics Technology, 11 Mar. 2016, https://www.ptonline.com/products/materials-pc-abs-with-a-density-advantage-for-automotive.
19] Based on tests results provided by one of the partners
20] Traces of PE were present for the material tested at CPMT
21] Melt Flow Index: More Than Just a Quality Control Rheological Parameter. Article in Advances in Polymer Technology · March 1986, Aroon Shenoy
22] Sisi Wang, Lore Capoen, Dagmar R. D'hooge & Ludwig Cardon (2017): Can the melt flow index be used to predict the success of fused deposition modelling of commercial poly(lactic acid) filaments into 3D printed materials?, Plastics, Rubber and Composites, DOI: 10.1080/14658011.2017.1397308
23] Published on October 2, 2014 Article updated on November 2. "Use of Recycled Plastics in Cars Is Shifting into Overdrive." *Plastics Make It Possible*, 2 Nov. 2017, https://www.plasticsmakeitpossible.com/plastics-recycling/what-happens-to-recycled-plastics/use-of-recycled-plastics-in-cars-is-shifting-into-overdrive/.
24] "Volvo Cars Aims for 25% Recycled Plastics in Cars from 2025." Volvo Cars Aims for 25 per Cent Recycled Plastics in Cars from 2025 | Volvo Car Group, https://group.volvocars.com/news/sustainability/2018/volvo-aims-for-25-per-cent-recycled-plastics-in-cars-from-2025.
25]Processability evaluation is based on MFI values

26]Based on the assumption that the shredded residue of car plastics [15] reflects the composition of plastics in a vehicle [1],[2]
27] The investigation of this application is based on one or few specific initiatives, so it isn't possible to provide general data about the sector
28] Retrieved from http://www.urbanmineplatform.eu/urbanmine/vehicles/weight.
29] McKinsey & Company. (2019). *How plastics waste recycling could transform the chemical industry*. [online] Available at: https://www.mckinsey.com/industries/chemicals/our-insights/how-plastics-waste-recycling-could-transform-the-chemical-industry.
30] PlasticEurope (2019) Plastics the Facts 2019