LIFE PlasPLUS

LAYMAN'S REPORT

MEETING THE CHALLENGE OF SEPARATING COMPLEX PLASTICS

SEPTEMBER 2023

www.lifeplasplus.eu - LIFE18 ENV/BE/000368

LIFE PlasPLUS

REPORT CONTENTS

"Recycling of high-quality secondary thermoplastics and recovery of critical raw materials (antimony) from mixed plastic waste in the automotive and the electrical and electronic equipment sector."

LIFE PlasPLUS

1. AT A GLANCE

FIVE EU PARTNERS

The project is run by a consortium of 5 EU partners covering the value chain for plastics recycling in automotive and flame retardant sector

Plastics Recycling
Automotive Value chain

F R Plastics Recycling
Antimony Value chain

comet traitements	SERIPLAST POLYPROPYLENE COMPOUNDS	CRF	LIÈGE université	Campine
Waste sorting and valorisation	Plastic compounding	Car manufacturing	Research and development	Production of antimony

PROJECT DATA

Belgium - Italy

2,4 M

1 M

July 2019 - June 2023

This project has received funding from the European Union's LIFE Programme for Environment and Resource Efficiency under grant agreement No. LIFE18 ENV/BE/000368.

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2. CONTEXT

51

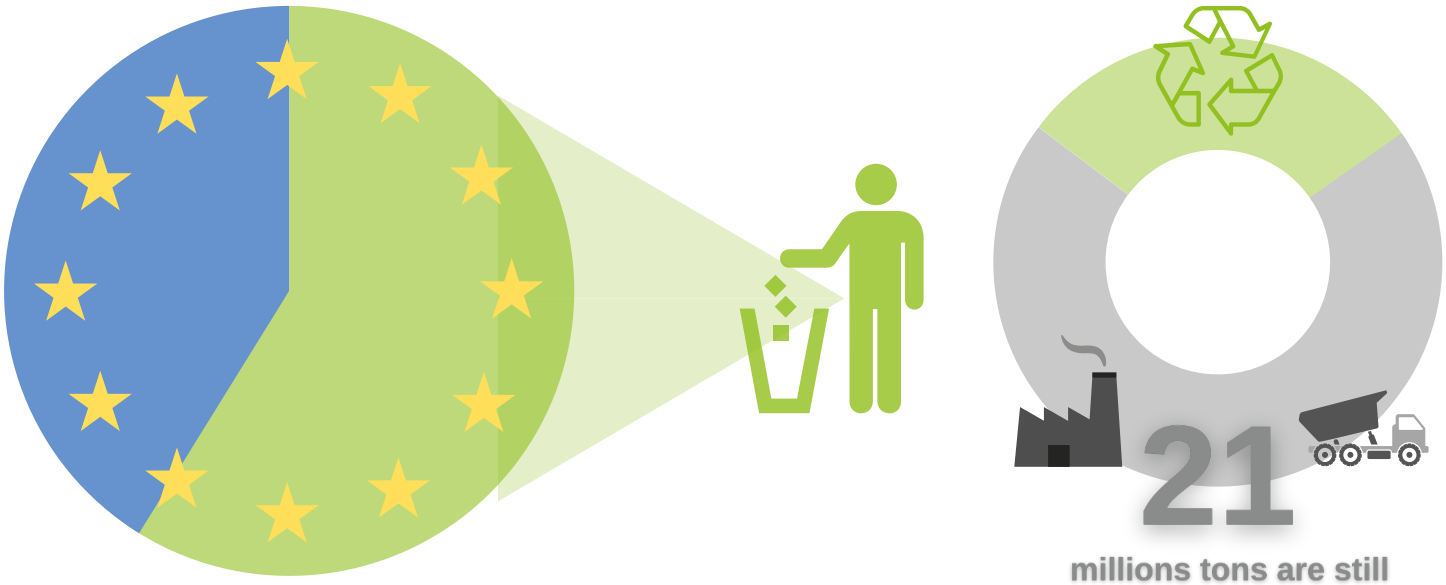
millions tons plastic used each year in Europe

30

millions tons post consumer waste plastics generated

9

millions tons of waste plastics is collected for recycling.



21

millions tons are still landfilled or incinirated

Thermoplastic waste from End-of-LIFE Vehicles (ELVs) and WEEE Waste from Electric and Electronic Equipments WEEE: an underexploited reserve of valuable plastic fractions

Every year, more than 51 million tons of plastic are used by the European economy. Only 30 million tons waste are collected.
This means that only 9 Mt plastics re-enter the European economy, mainly in the form of permanently downgraded recyclates with a short service life, ultimately landfilled or incinerate, and hence valuable materials, e.g. antimony (Sb) a commonly used flame retardant (FR) synergist, are permanently lost.

Owning to their exemplary technical and economic characteristics, thermoplastics constitute a continuously increasing fraction of the overall plastic waste in Europe. Low weight/density, cost-effective production, ease of use against machinability and the possibility of using many adjuvants explain their ever-growing demand.

2. CONTEXT

The vehicle market has seen an increased application of thermoplastics since 1970. In 2022, more than 7 Mt thermoplastics were consumed by the fast-growing automotive and electrical and electronic equipment manufacturing sectors (EEE) in Europe, namely polypropylene (PP), polyethylene (PE), acrylonitrile butadiene styrene (ABS) and polystyrene (PS).

A thermoplastic is any plastic polymer material that becomes pliable or mouldable at a certain elevated temperature and solidifies upon cooling.

- **If the thermoplastic streams could be adequately sorted and separated from non-recyclable fractions, they could be reused as a much higher-value feedstock.**

- **However, state-of-the-art recycling processes fail to capture the environmental and economic benefits of such a circular approach.**

Obstacles encountered to recycle thermoplastics are among other, low current processes' yield (about 50%), difficulty in obtaining economies of scale, and the presence of additives such as fillers. These challenges are further exacerbated by the presence of flame-retardant substances, such as bromine and antimony, which hamper and constrain the throughput and efficiency of recycling and block the much-needed access to high-quality high-price market segments.

As a result, secondary thermoplastics derived from waste EEE (WEEE) and End of Life vehicles (ELV) Shredder Residues cannot meet the high-quality specifications by the stringent automotive and electronics industries

3. PROJECT - OBJECTIVES

LIFE PlasPLUS

Meeting the challenge of recycling complex plastic mixtures

LIFE PlasPLUS revisits the concept of recycling with its holistic approach to simultaneously close the loop for two traditionally siloed material value chains, plastics and minerals, by producing high purity recycled thermoplastics and antimony.

These two materials in high demand, notably for the emerging electric mobility sector requiring the increased use of lightweight materials and flame retardants to, respectively, lower energy consumption and increase fire safety.

51
Sb
Antimony
121.760

Europe has identified antimony as critical raw materials with a high supply risk. It is present in particular in flame retardant plastics, for which today no recycling route does exist. Flame retardants are a varied group of substances with the primary purpose of inhibiting ignition in combustible materials as well as slowing the speed of propagation of a fire. Flame Retardants are essential to protect lives and property. 29% do use halogenated system in particular brominated flame retardants. Antimony trioxide as it is used as flame retardant synergist in brominated flame retardant plastics, is present in brominated flame retardant plastics.

3. PROJECT - OBJECTIVES

LIFE PlasPLUS

Meeting the challenge of recycling complex plastic mixtures

The project – for the first time in Europe – will demonstrate an integrated, and replicable solution for:

- Preventing the downcycling of high-quality secondary ABS, PS and mineral filled (F)PP regrinds and by-products in commingled shredder residues (SR) coming from end of- life vehicles and WEEE

- Integrating secondary plastic and Sb into compounds and products to unlock direct EU-wide substitution of virgin resources in automotive, EEE and other sectors

Ultimately, LIFE PlasPLUS's implementation will serve as a successful case study of a closed loop approach for valorising a currently wasted resource and transforming it to added-value raw materials and products.

Aims to improve the recycling of high-purity secondary thermoplastic and enhance a circular value chain

Recover Antimony, a critical raw material, coming from plastic waste in WEEE sectors

3. PROJECT - OBJECTIVES

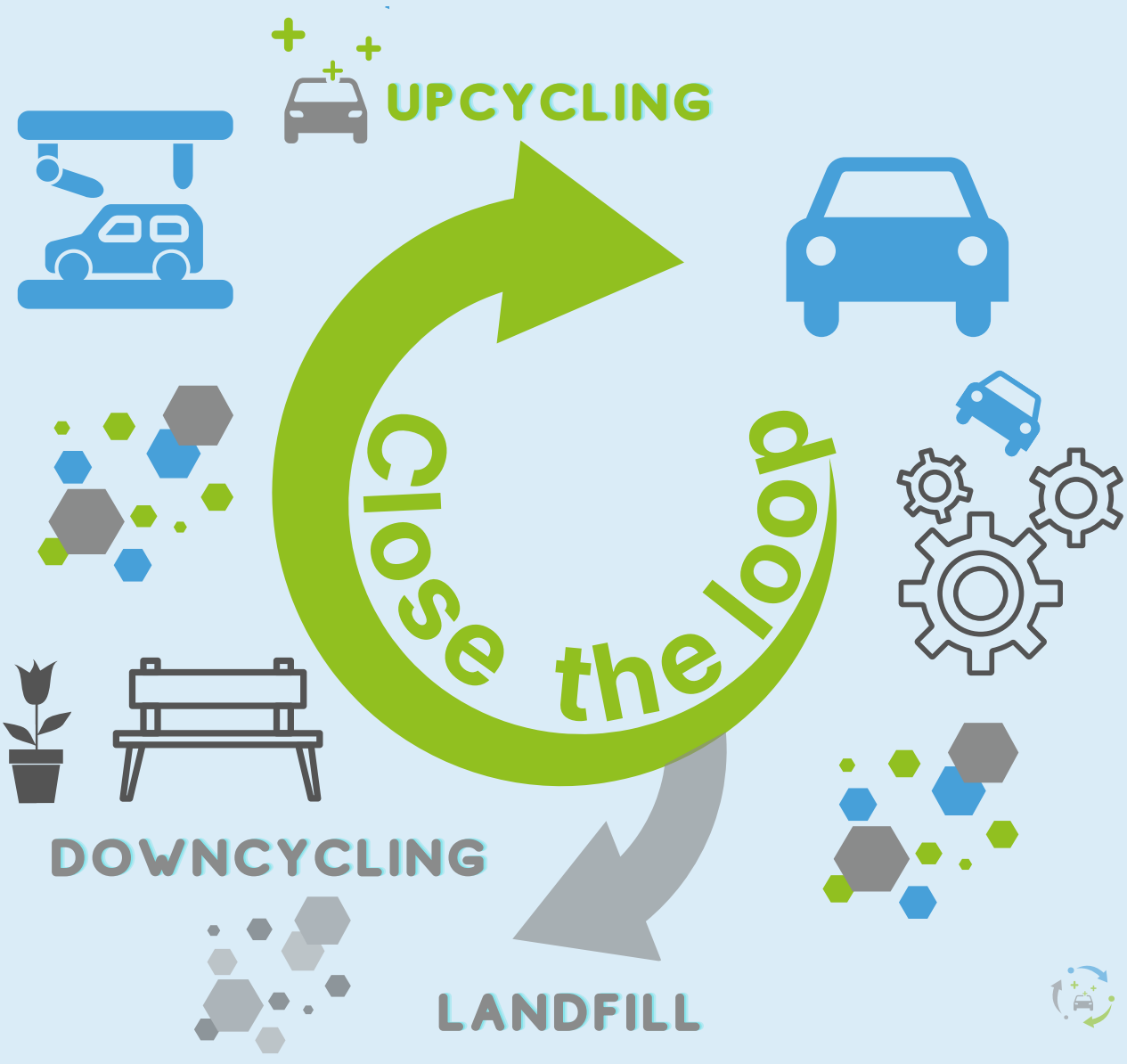
1. Demonstrate the feasibility of recycling 45% of the initial plastic waste entering Comet plant to added-value thermoplastic streams (> 98% pure PS, FPP and ABS regrinds)
2. Unlock future valorisation of recyclable technical plastics by adapting a sensor based separator that can detect Flame Retardant Plastics, and separate them from the rest of the mix
3. Substitute > 40% virgin thermoplastics with secondary ones in 3 new secondary compounds destined for the stringent automotive and EEE markets
4. Validate the quality of the produced compounds in 3 standard vehicle parts (for the automotive sector) as well as in flame-retardant masterbatches (for the EEE sector)
5. Showcase a “closed-loop” production of plastics with antimony for flame retardancy
6. Conduct thorough LCA and socio-economic analyses to confirm the environmental benefits and techno-economic soundness of the concept
7. Develop a replication and transfer plan for facilities around Europe

3. PROJECT - OBJECTIVES

Closing the loop in the automotive sector : showcasing waste thermoplastics upcycling

LIFE PlasPLUS targets an innovative technology challenging the current state-of-the-art recycling process and transforming the current downcycled or landfilled/incinerated waste in high-purity secondary thermoplastics.

The project enables high quality recycling, or "upcycling", of high-value thermoplastics by ensuring their recycled version can be used in vehicles with exactly the same applications as the original component made of virgin resins.



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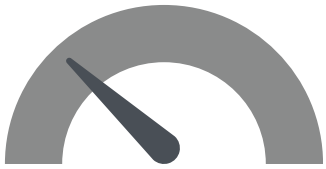
3. PROJECT - R&D APPROACH

The innovative approach will transform previously downcycled or landfilled/incinerated waste through three successive steps:

1 Production of high purity thermoplastics



Plastic light fraction with density < 1,08 containing mixes of ABS, PP, PE, PS and Filled PP (FPP) enter this step.

The aim is to demonstrate that tribo-electric separation allows the extraction of FPP from PS and ABS mixes hence, enabling the production of high purity regrinds from heterogeneous waste streams.

2 Sensor based sorting and separation of FR Plastics (FRP)

Selective extraction of Flame Retardant Plastics out of the heavy waste plastic fraction is processed through a sensor based sorting line .

The XRF sorting technology was used to separate FRP from the heavy residual plastic fraction while the PICKIT technology developed by ULiege was leveraged to extract residual Printed Circuit Board (PCB) cards left in the FRP stream.

3 Recycling of by-product Sb through catalytic conversion and hydrometallurgy

The antimony rich char produced by catalytic conversion were then processed to obtain ATO or other Sb based products for industrial applications.

Two routes have been investigated :

1. hydrometallurgical route
2. pyrometallurgical smelting route

3. PROJECT - R&D APPROACH

Recover thermoplastics & antimony from FR plastics

Demonstrate plastic upcycling in automotive parts & EEE sector

Mixed plastics from ELV and WEEE shredder residues

Density separation

Separation by existing state of the art infrastructure

Density separation

Ultimate Waste

STEP 1 Innovative separation technique

STEP 2 Sensor based separation

Flame retardant plastics

STEP 3 Catalytic cracking (batch process)

PP3 (PE/PP)

PS *ABS* *Filled PP*

Heavy plastics mixes to landfill

Br Sb chemical compounds, heat & electricity

Upcycling

Vehicle compounds

Flame retardant masterbatches

Quality validated

Manufacture of new products

3. PROJECT - R&D APPROACH

INNOVATIONS BROUGHT BY THE PROJECT

Separation of complex ternary plastic mixture from post-consumer waste to produce high purity “single plastic” streams of ABS, FPP, PS at industrial level

Closing the loop in automotive and EEE sector for ABS & FPP, notably by demonstrating the upcycling of high-value End of Life thermoplastics in car interior parts

Extract brominated flame retardant plastics containing antimony & Printed Circuit Boards from complex plastic waste streams

First of a kind demonstration of an antimony recovery route for brominated flame retardant plastic waste streams

3. PROJECT - R&D APPROACH

Demonstrate plastic upcycling in automotive parts & EEE sector : methodological approach

One important objective of PlasPLUS is to showcase the re-use of purified recycled thermoplastics in automotive car parts. To do so a 4 steps methodology has been developed:

PlasPLUS Upcyling Methodology for the automotive sector

Select targeted plastic car part

Start with its material specification sheet

Design new compliant's compound formulation with high recycled content

Manufacture the part in pre-series & validate final compliance

3. PROJECT - RESULTS

STEP 1 PRODUCTION OF HIGH PURITY THERMOPLASTIC

High purity thermoplastics production & upcycling in end products

This step being the first one in the project value chain, it has been the one first implemented and is now fully achieved and fulfills project objectives with the demonstration at industrial scale of the production of purified thermoplastics : **8,687 tons of purified secondary plastics (FPP & ABS at 98% purity, PS 95% purity) have been produced and sold to Comet Traitements' compounder customers.**

It was demonstrated that desired quantities and qualities of recycled thermoplastics can be obtained with the tribo-electric unit commissioned by Comet and now in operation.
In particular the products were shown to be **fully compliant with RoHS regulations**

The last project period, from start 2022 to May 2023 was devoted to the production and validation of LIFE PlasPLUS tailored **intermediate and final products in the automotive and EEE sectors.**

The methodology was to :

1

Start from the design new compounds incorporating recycled plastics from shredder residues.

It was based on the **material specifications sheets for the automotive and EEE sector**. Two PP compounds for semi-structural parts interior and/or exterior were selected and two for ABS regrinds.

3. PROJECT - RESULTS

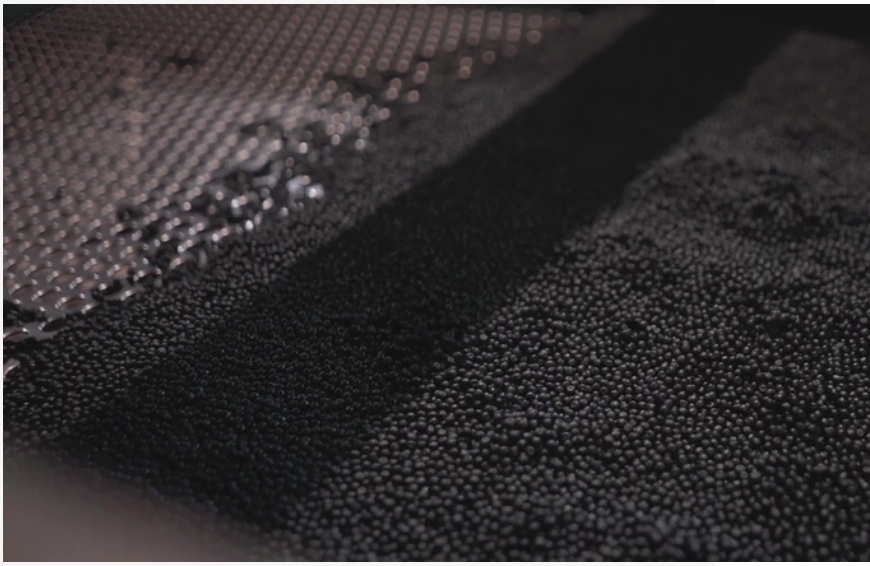
STEP 1 PRODUCTION OF HIGH PURITY THERMOPLASTIC

High purity thermoplastics production & upcycling in end products

2 **Perform the compounding in order to fulfill the compliance with spec sheets requirements.**

Comet Traitements supplied large scale samples to the consortium's compounder : Seriplast.
Two tons of FPP Regrind and 2 tons of ABS Regrind were shipped to Seriplast

Seriplast adjusted the main parameters of their extrusion process equipment (feeding system, temperature gradient, throughput, others) to produce new compounds.
It was possible for Seriplast to produce a compound made of 100% recycled FPP with the main mechanical properties being attained.
This greatly surpasses the **project's objective of 40% reduction** in the use of virgin plastic for the manufacture of new products.



3. PROJECT - RESULTS

STEP 1

PRODUCTION OF HIGH PURITY THERMOPLASTIC

High purity thermoplastics production & upcycling in end products

For ABS, it was decided to target a compound made of a mix of ABS and PC (Polycarbonate) to obtain similar properties as a commercial compound used for car interior parts. Different composition were tested, with various mix of virgin vs recycled ABS.

Use of recycled ABS from Comet in combination with both virgin ABS and glass fibers was positively demonstrated.

3 **Validation of the compound compliance with spec sheet**

Seriplast carried out several analytical tests in the lab to assess the compounds' mechanical characteristics (e.g. MFI, VICAT, IZOD, Flexural Modulus, Traction Test ...). It ended up with **a full validation of the compounds compliance.**

Finally compound batches of 200 kg, were produced and shipped to CRF.

3. PROJECT - RESULTS

STEP 1

PRODUCTION OF HIGH PURITY THERMOPLASTIC

High purity thermoplastics production & upcycling in end products

4 **Injection molding of interior part and validation of mechanical properties**

CRF selected and produced **2 different car interior parts** :

- A **glove box** – FIAT 500 - based on FPP compounds made of Comet 100% recycled FPP regrinds
- **Speaker adaptors** based on ABS – PC – Glass fibers coumpound.

Injected part

The injection moulding process was optimized to guarantee aesthetical, functional and dimensional properties. Achieved surface quality showed to be acceptable.

Quality validated

The parts were validated under **thermos-mechanical Stellantis standard procedures.** Deformations appeared to be inside the standard limits.

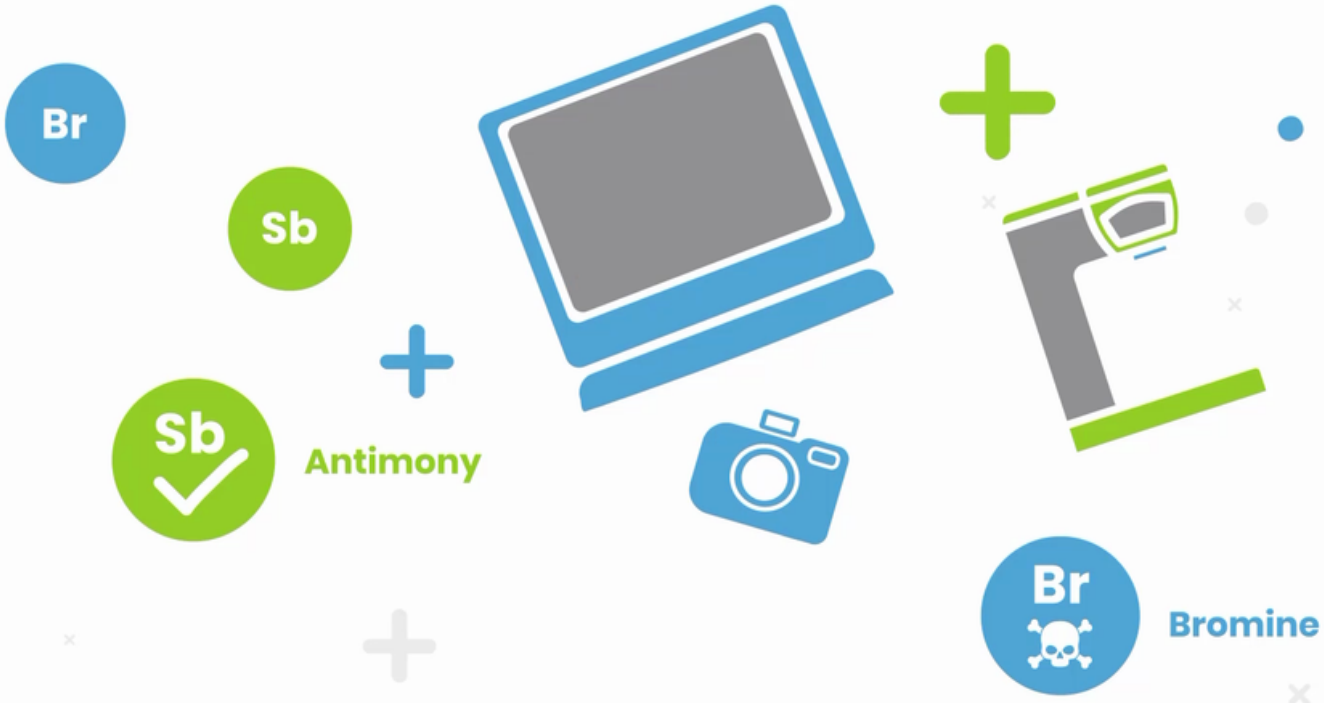
3. PROJECT - RESULTS

STEP 2 SENSOR BASED SORTING AND SEPARATION OF FLAME RETARDANT PLASTIC (FRP)

Extraction of Flame Retardant Plastics

In the framework of the LPP project, Université de Liège adapted the PICKIT technology, a robotic sorting line with real-time multi-sensors acquisition, to identify and extract Flame Retardant Plastics ("FRP") containing elements such as Br and Sb by modifying its LIBS-based detection system.

Extraction of FRP was targeted on Comet's heavy plastic fraction 'Drainaplus' which is the commercial name for the Comet's non-recyclable plastics with a density over 1.08 g/cm. This plastic fraction enriched in FRP is obtained by density separation in Comet's plastic plant.

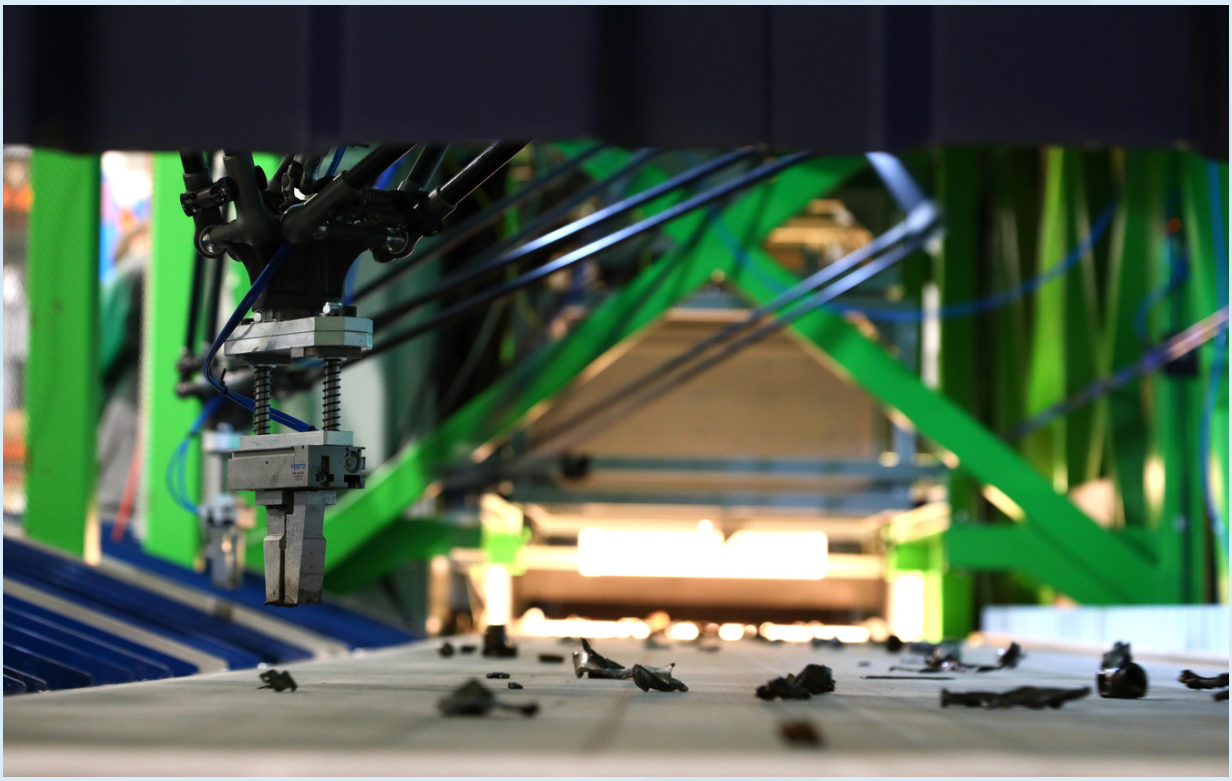


3. PROJECT - RESULTS

STEP 2 SENSOR BASED SORTING AND SEPARATION OF FLAME RETARDANT PLASTIC (FRP)

Extraction of Flame Retardant Plastics

The adaptation of the PICK-IT technology to plastic turned out to be much more complicated than anticipated to identify and isolate flame-retardant plastics (FRP), due to surface contamination by magnetic particles.



Industrial progress independent of LIFE PlasPLUS, resulted in the emergence of an XRF technology to separate FRP from WEEE and ELV waste plastic streams. To align itself on these new developments, the LPP partners relied on the REDWAVE XRF sorting technology. Two XRF sorting campaigns were successfully conducted in February 2021 and April 2022 to produce 1.2 tons of high-grade bearing Sb plastic.

Research activities however progressed on PICKIT, led to several findings, with potential exploitation. PICKIT system is able to differentiate and sort Printed Circuit Board (PCB) cards out of the FRP streams. PCB contains a significant amount of copper and precious metals that could be valorised.

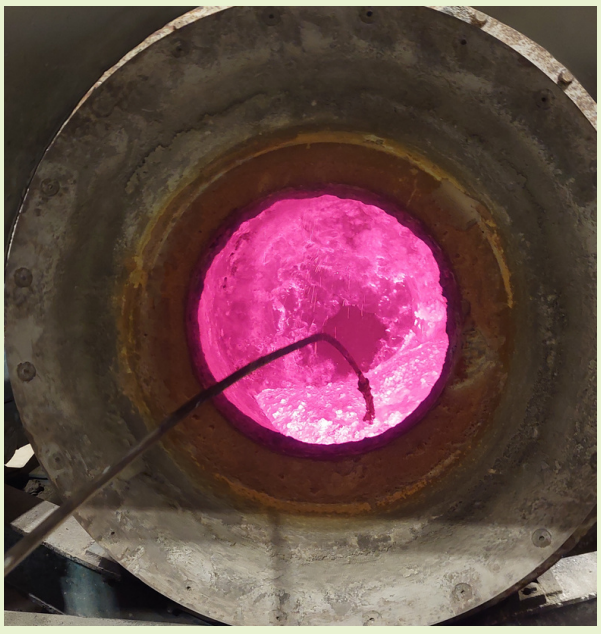
3. PROJECT - RESULTS

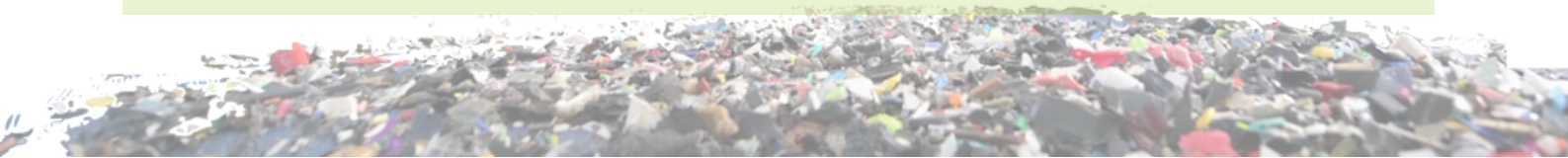
STEP 3 RECYCLING OF BY-PRODUCT ANTIMONY (SB) THROUGH CATALYTIC CONVERSION AND HYDROMETALLURGY

COM characterized and performed the catalytic conversion of FRP generated with the XRF technology through 5 lab-scale and 3 semi-industrial scale campaigns which treated a total of 1,229 kg of FRP and delivered a total of 402 kg of Sb-Char at a grade of 5% Sb.

Sb-Char produced by catalytic conversion were then processed to obtain ATO or other Sb based products for industrial applications. Two routes were developed: hydrometallurgical route (ULI) and pyrometallurgical smelting route (CAM). The last one were experimented at pilot-scale, giving 1,8 kg Sb2O3 available for the production of a flame retardant masterbatch in compliance with the expected project results.

The recovered antimony trioxide is not 100% pure as was wanted and expected. The process still needs some optimisation activities, to be planned after project end. However, the proposed pyrometallurgical route succeeded at industrial level in purifying antimony trioxide, only present in 5% - 7% in the char.





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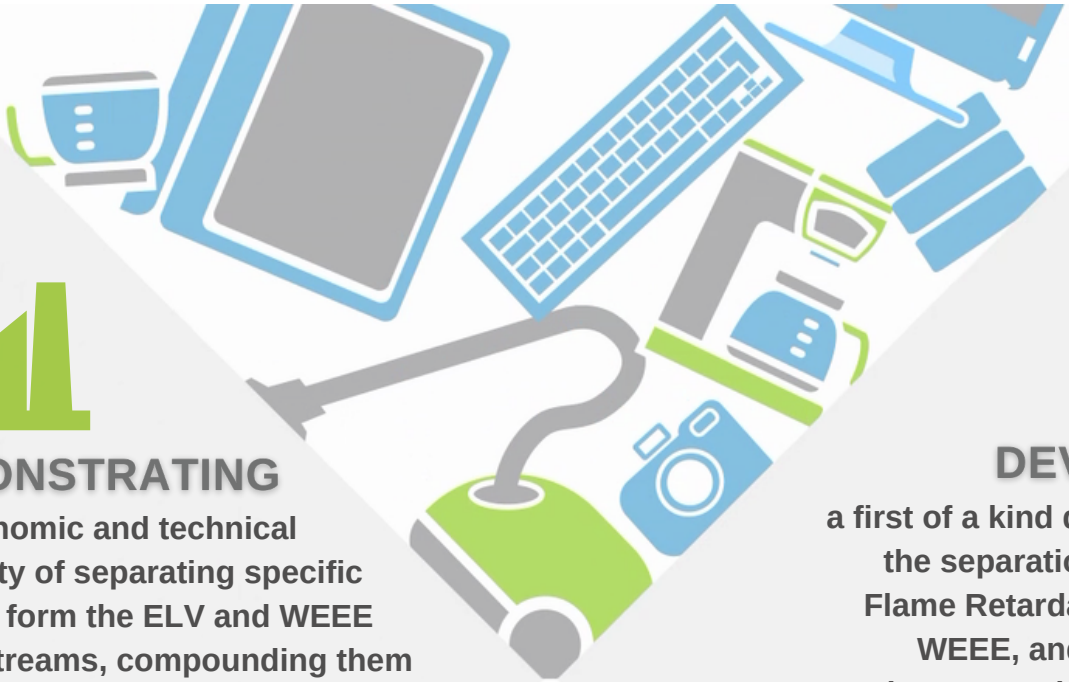
4. IMPACTS - INDUSTRIAL

PLASPLUS CONTRIBUTES TO THE TRANSITION TOWARDS A CIRCULAR ECONOMY, BY SUCCESSFULLY :



DEMONSTRATING

the economic and technical feasibility of separating specific plastics form the ELV and WEEE waste streams, compounding them and reinserting them into the production process instead of virgin plastics

DEVELOPPING

a first of a kind demonstration of the separation of brominated Flame Retardant Plastics from WEEE, and the recovery of antimony, a critical raw material

At the end of the project , the plastic purification unit is already in operation. With a future capacity of 50,000 tons per year of mixed plastic waste input from ELV & WEE, it will enable the production of 16,000 t/y purified thermoplastics (ABS, FPP, PS, PE/PP mix) ready to re-enter the automotive and EEE markets.

Upcyling has been demonstrated with high impact on European circular value chains

Car interior part with FPP recycled content up to 100% have been showcased : the manufactured part fulfils end user automotive requirements for the same part made of virgin resins.

It open the door to the development of circular, closed loop recycling in the automotive and EEE sector from complex plastic mixes obtained by shredding ELV and WEEE in the same recycling plant.

LIFE PlasPLUS

Demonstrated closed loop recycling fully contributes to European policies on recycling ELV. In particular to the revision of European ELV Directive, Commission proposal of July 2023, that sets objectives in recycled plastic content target of 25% in new cars. It fully fits with Life PlasPLUS strategy to upcycle thermoplastics in the automotive sector.

Replication potential is high :

The plastics which are separated at significantly higher purity rates, have a higher value in the market and 8,687 tons of purified ABS, FPP and PS have been sold to customers during project completion demonstrating its market potential. Given the very positive technical results obtained by the separation and purification unit, some existing customers have now been asking to treat their mixed thermoplastics at Comet's facilities given their inability to treat their mixed thermoplastics on their current industrial sites.

Detailled business plan of the plastic plant indicates a payback time of 4 years. The plastic purification plant is fully profitable.

As the EOL vehicle and WEEE waste streams throughout Europe propose similar characteristics, **the replicability of LPP's technology is assured.**

Upscaling the plant and replicate it in Europe is part of the after LIFE plan.

4. IMPACTS

A full Life Cycle Analysis (LCA) conducted during the project enabled to quantify the PLasPLUS processes' environmental benefits. The LIFE PlasPLUS technologies contributes to :

Reduced water consumption

In comparison with virgin resin production of the same amount of thermoplastics

Reduced energy consumption

Reduced greenhouse gases emissions

90%

90 % CO2 eq. emissions reduction for the production purified secondary plastics (FPP & ABS at 98% purity, PS 95% purity) in comparison to the production of equivalent virgin resins

28,000 tons

28,000 tons CO2 emissions saved per year when the plastic production unit will run at full capacity, in 2024

5,310 tons

5,310 tons CO2 eq. emissions saved during last year operation of the plastic purification unit.

51
Sb
Antimony
121.760

Resource Depletion of minerals & metals impact

The antimony recovery routes were shown to be a very relevant development of the project, with normalised results indicating a very important potential benefit on the Resource Depletion of minerals & metals impact category

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4. IMPACTS

Waste management impacts

When the plastic production will run at full capacity, in 2023, 16,750 tons of recycled thermoplastics will be diverted from landfilling per year

16,750 TONS DIVERTED FROM LANDFILLING PER YEAR

Social benefits

The project has positive impact on health, as it has prevent plastic waste to be landfilled or incinerated and thereby contributing to the circularity of the EU economy.

Policy implications

LPP will contribute to the development of approaches for circular economy by waste recovery and valorisation. Plastics are an important part of European waste streams and are still largely landfilled and incinerated. As plastics can be separated more precisely and re-used with higher purity, the project will have a big impact on the following policies:

- **ELV Directive** (2000/53/EC) and its revision (2023)
- **Landfill Directive** (EU 2018/850): The project aims at diverting a wider proportion of ELV and WEEE plastics from landfill.
- **European Strategy for Plastics in a Circular Economy** (COM/2018/028 final)
- **The WEEE Directive** ((EU) 2012/19): The project tackles the problem of FRPs in the WEEE recycling stream, by enabling these components to be identified in an automated and rigorous manner.
- **EU Raw Materials Initiative** (COM/2008/0699 final): The project demonstrates a recycling route for Sb, a Critical Raw Material with a very high supply risk

5. CONTACTS

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