LIFE PlasPLUS

MEETING THE CHALLENGE OF SEPARATING COMPLEX PLASTICS

After LIFE Plan

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.

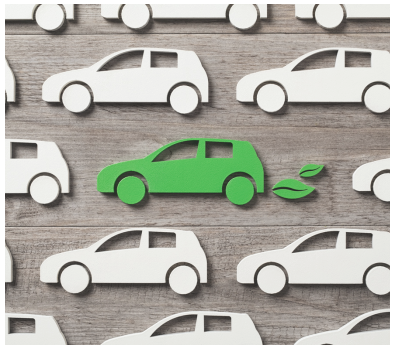
www.lifeplasplus.eu - LIFE18 ENV/BE/000368

LIFE PlasPLUS

INTRODUCTION

Meeting the challenge of recycling complex plastic mixtures

LIFE PlasPLUS project is an innovative, close-to-market four-year project, dedicated to the recycling of complex plastics mixes from ELV's (End of Life Vehicles) and WEEE's (Waste from Electric & Electronic Equipment) shredder residues that are today landfilled or incinirated.



PlasPLUS succeeded in producing high purity thermoplastics and recycled-antimony to re-introduce them in high quality technical end user part in the automotive and EEE sector.

This After-LIFE Action Plan describes here the project's approach, its results and activities foreseen after project's end to fasten the market introduction and maximize impact through dissemination to relevant stakeholders.

PROJECT PARTNERS

LIFE PlasPLUS was run by a consortium of 5 EU partners covering the value chain for plastics recycling in the 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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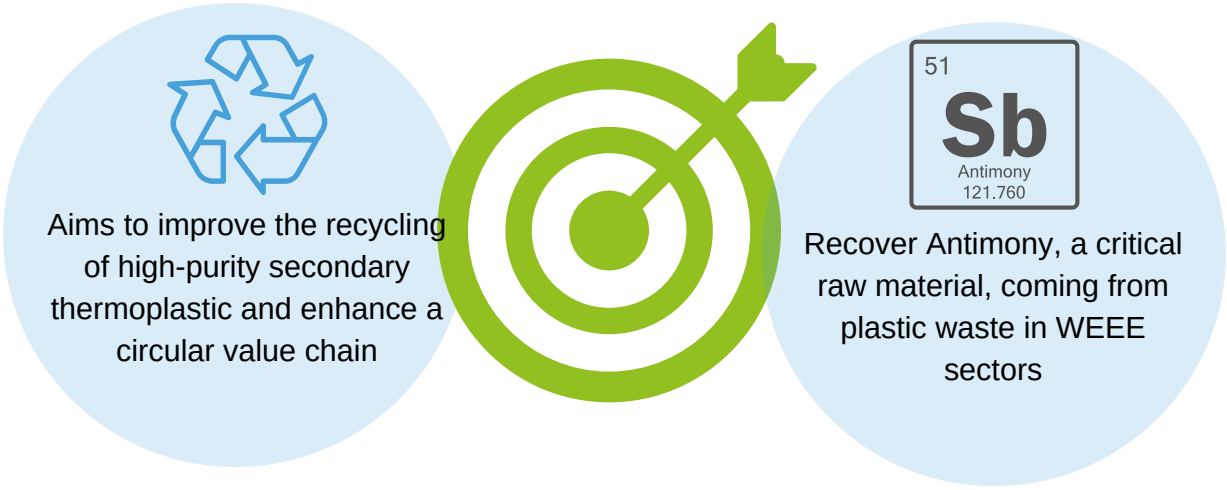
OBJECTIVES OF LIFE PLASPLUS

LIFE PlasPLUS addresses the problem of recycling complex heterogeneous plastic wastes 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.



The project brings 4 innovations on the market:

1. Separation complex ternary mixtures of plastic from post-consumer waste and producing high purity ABS, FPP, PS at industrial level
2. Closing the loop in automotive and EEE sector for ABS & FPP
3. Extract brominated Flame Retardant Plastics (FRP) containing antimony & PCBs from complex plastic waste streams
4. First of a kind demonstration of an antimony recovery route from plastic waste streams

The project demonstrates, for the first time in EU, 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 ELV (End of-Life Vehicles) and WEEE
- Integrating secondary plastic and antimony (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.

The project was organized around 7 initial objectives:

1. **Demonstrate the feasibility of recycling 45% of the initial plastic concentrate** reaching the recycling plant to added-value thermoplastic streams (> 98% pure PS, FPP and ABS regrinds) by upscaling a triboelectricity demo unit from its current prototype system level (batches, TRL6) to pre-commercial level (continuous, TRL7)
2. **Unlock future valorisation of recyclable technical plastics** by adapting a sensor enabled separator that can detect FRPs and separate them from the rest of the mix
3. **Substitute > 40% virgin thermoplastics with secondary ones** in 3 new secondary compounds (1 ABS and 2 PP) destined for the stringent automotive and EEE markets
4. **Validate the quality of the produced compounds** in 3 standard vehicle parts (for th automotive sector) as well as in flame-retardant masterbatches (for the EEE sector
5. **Showcase a "closed-loop" production for valuable FR element, Sb_2O_3, Antimony Tri-Oxide (ATO)** which derives from the "Critical Raw Material"- classified Sb, also validating its performance in recycled plastics for flame retardancy
6. **Conduct thorough LCA and socio-economic analyses to confirm the environmental benefits and techno-economic soundness of the concept** in support of future continuation, replication and transfer
7. **Develop a replication and transfer plan** as the technologies are replicable and scalable and can be translated into sustainable business models for facilities around Europe

Project R&D approach

R&D implementation was structured on a 3 step approach:

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 bu 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

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RESULTS

STEP 1 PRODUCTION OF HIGH PURITY THERMOPLASTICS

This step was the one first implemented and was successfully achieved. It demonstrated at industrial level the production of purified thermoplastics : 8680 tons of purified secondary plastics (FPP & ABS at 98% purity, PS 95% purity) were produced and sold to Comet Traitements' compounder customers. The products were shown to be fully compliant with RoHS regulations.

One important objective of PlasPLUS was to showcase the re-use of purified recycled thermoplastics in automotive car parts. Two car interior part were targeted: a Fiat 500 Glove Box based on FPP and a speaker adaptor for the ABS upcycling validation.

To do so the following methodological steps were adopted:

- Define the compounds requested and their specification sheets. Two PP compounds for semi-structural parts interior and/or exterior were selected and two for ABS.
- ·Optimize the compounding formulation to obtain full compliance with spec sheets requirements and validate its manufacturability.
- Injection moulding of interior part, validation of its mechanical properties and optimization of the process to guarantee aesthetical, functional, and dimensional properties. Achieved surface quality showed to be fully acceptable.
- The parts were validated under thermo-mechanical automotive standard procedures, deformations appeared to be inside the standard limits.

LIFE PlasPLUS demonstrated the usage of post shredded PP and ABS for automotive applications in different location of the vehicle fulfilling all end user requirements

A similar approach on end user EEE application led to the same conclusion

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.

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

Extraction of FRP was targeted on the Comet's heavy plastic fraction : non-recyclable plastics with a density over 1.08.

Two technologies were tested:

- 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,
- Binary XRF sorting technology developed industrially by REDWAVE company.

Two XRF sorting campaigns were conducted successfully in February 2021 and April 2022 to produce 1,2 tons of high-grade bearing Sb plastic.

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. Research activities however progressed on Pick-IT, 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.

STEP 3. RECYCLING OF BY-PRODUCT ANTIMONY THROUGH CATALYTIC CONVERSION AND HYDRO/PYRO METALLURGY

COMET 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 (ULiège) and pyrometallurgical smelting route (CAMPINE). 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 objetctives.

The recovered antimony trioxide is not 100% pure as it 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.

IMPACT: ENVIRONMENTAL

A full Life Cycle Analysis (LCA) conducted during the project enabled to assess the PLasPLUS processes' environmental benefits. Project contributes to :

- Reduced water consumption in comparison with virgin resin production of the same amount of thermoplastics
- Reduced energy consumption

Reduced greenhouse gases emissions

In particular :

- 90 % CO2 eq. emissions reduction in the production purified secondary plastics (FPP & ABS at 98% purity, PS 95% purity) in comparison to the production of equivalent virgin resins
- 16,750 tons of recycled thermoplastics will be diverted from landfilling per year
- 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.

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): 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

IMPACT: 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.
- Developing 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 capacity of 50,000 tons per year of mixed plastic waste input from ELV & WEE, it will enable the production at short term 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.

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.

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ACTIVITIES FORESEEN AFTER THE PROJECT'S END

The replication potential is high for the thermoplastic sorting and purification unit :

- The plastics which are separated at significantly higher purity rates, have a higher value in the market
- 8,687 tons of purified ABS, FPP and PS have been sold to customers during project completion demonstrating its market potential.
- Detailed business plan of the plastic plant indicates a payback time of 4 years. The plastic purification plant is fully profitable.
- As the End of Life vehicle and WEEE waste streams throughout Europe propose similar characteristics, the replicability of PlasPLUS's technology is assured.

Upscaling the plant and replicate it in Europe is then part of the After LIFE plan

Favourable socio-economic context

After LIFE activities will benefit of a quite favourable socio-economic and environmental context. The European Commission proposed in March and July 2023 two new European directive proposals in the circular economy, the Critical Raw Material Act that sets objectives in terms of recycling of CRMs, and antimony is one of them, and the new ELV directive. In parallel all automotive OEMs have themselves set ambitious zero carbon footprint targets for 2035 – 2040. Mechanical recycling of plastics is part of their plan.

New proposed ELV directive is a game changer and will contribute to the decoupling plastic recyclates price from virgin resin prices and a dramatic increase of the demand for recycled PP, ABS and other Thermo-Plastics.

As a result, a huge demand recycled thermoplastics is to be anticipated in next 3 – 7 years.

Activities #1: Dissemination and awareness campaigns

After LIFE Project communications and dissemination activities will be centred around achieving the following objectives:

- Raise awareness about LIFE PlasPLUS project and its goals to create wide-spread visibility of the scope of work.
- Disseminate project information and data on industrial applicability and exploitability of the results to the market stakeholder and industry.
- Highlighting the economic advantages and the environmental advantages for the community.
- Inform and convince more industrial stakeholders as well as other value chain actors of the capacity of PlasPLUS technologies to close the loop in the automotive and EEE sector.
- Spread information on technological breakthroughs and results for educating, stimulating further research or exchange knowledge.

Chanels :

- Website, social medias : Newsletters are planed to be published in 2024-2026 as well as news on the after LIFE activities
- Conference an fairs : partner of the project will actively participate in events to presents the results and last development of PlasPLUS project.
- B2B meetings with stakeholders & visit of Comet's plant.
- Participation in working groups of EU association.

Targeted actors:

- Automotive and EEE OEMs, Tier1, compounders and other suppliers
- EU or national circular economy associations and their working groups : EURIC, Plastics Recyclers, Plastic Erurope, EuPC, Denuo, ...
- Research community active in the circular economy.
- Public bodies : EU Commission and its agencies, environmental associations, ...

Activities #2: Ramp up & upscale the thermoplastic purification plant

1-3 years after project's end :

- Ramp up the production to reach full capacity (50kt/y).
- This will be eased by the favourable socio-economic context : ELV & WEEE feedstock are expected to grow in the coming years as well as the demand in recycled plastics.
- B2B collaboration will be sought with value chain actors, in order to secure waste feedstock and sales.

2-4 years after the end of the project:

- **Upscale COMET plant to 100,000 t/y**
  - Double the equipment
  - Upscale the building : +75% property costs
  - Increase staff : + 50 %

Business plan indicates economy of scale and reduced payback time

- **Capture more feedstock**
  - It will increase gradually due to market growth (EEE, automotive), and with the first impacts of the new ELV directive,
  - Set up direct agreements with OEMs to get more ELVs,
  - Set up collaboration agreements with compounders or Tier 1 producers.

- **Secure and increase sales:**
  - Automotive: convince value chain actors of the quality, quantity of the recyclates,
  - EEE : establish direct contact with EEE OEMs (currently on their compounders),
  - Showcase end products made of recyclates using LIFE PlasPLUS results,
  - Continue to prospect compounders (ongoing activity),
  - Prospect plastic transformers.

Activities #3: Replication at other European sites

To capture feedstock located abroad, far from Belgium, replication is the right option given the transport costs and its negative carbon footprint. The aim is to develop recycling plants in different European geographical areas large enough collect enough ELV or WEEE. Replication investment isn't an obstacle as the COMET plastic plant with a payback time of 4-5 years is profitable.

The activities are to:

3-6 years after the end of the project (once ELV directive adopted – probably in 2025) :

- Installing plastic plant abroad,
- Establish agreements with OEM for closed loop recycling,
- Develop compounds portfolio with OEMs and their Tier 1 converters and/or their compounders,
- Collaborate with shredder companies located in the geographic zone.

Activities #4: Participating actively in the development of the new value chain & business model with key value chain actors

The automotive sector will face the major challenge of becoming more circular coming years. The current automotive virgin resin plastic value chain has to adapt:

- OEMs, Producers (Tier1), and their compounders have to develop compound formulations integrating recycled plastics,
- OEMs should integrate recyclers in their supply value chain.

Activities will seek to support the development of this new value chain:

- Showcasing the closed loop recycling LIFE PlasPLUS results, as many OEMs are still not convinced of this, through direct B2B contact, dissemination activities and developing additional upcycled end products (new car parts with new compounds),
- Demonstrating that qualities, volumes and stability can be guaranteed and secured, at acceptable prices,
- Developing LCA, carbon footprint and traceability of the recycled products,
- Prepare future supply chain standards (end of waste, carbon footprint index) and/or seek for more uniformity in the approach,
- Position mechanical recycling in the new business models : 9R, eco-design. In particular the way dismantling, re-use, mechanical recycling and chemical recycling will work together,
- Improve the communication along the value chain.

Activities will be developed in collaboration with:

- OEMs, Tier 1, Compounders trough B2B or R&D relationships. Project partners, CRF and SERI-PLAST, with Comet will continue to collaborate on after LIFE activities
- Recyclers and associated European/ National associations : EURIC, PRE, EuPC, DENUO, Plastics Europe
- Public authorities, environmental associations and civil society stakeholders

Activities #5: replicate compounds formulations on other end user applications

It will be necessary for the future market to replicate the compounds formulations with recycled ABS & FPP to other car interior part or EEE applications, with other formulations, and showcase closed loop on other car parts or EEE applications

Future R&D efforts will concentrate on other thermoplastics separation and showcasing closed loop recycling in end user applications.

The strategy will be:

- To prioritize collaboration with Tier 1 converters
- Create a full compound portfolio with recycled thermoplastics
- Develop expertise and showcase the upcycling on multiple compounds and end user application

Activities #6: improve recovered antimony purity and its production trough optimization of the process & develop the market.

Antimony recovery route indicated very important environmental potential benefits.

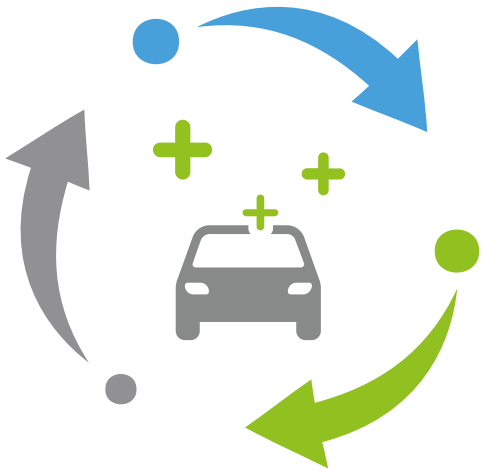
As the recovered antimony trioxide is not 100% pure as was wanted and expected, After LIFE plan will be then devoted to the optimisation of the process's steps. However, as the proposed pyrometallurgical route succeeded at industrial level in purifying antimony trioxide, only present in 5% - 7% in the char, efforts will be also devoted to seeking directly industrial collaborations to implement the technology across Europe. Collaboration will be sought with shredders processing WEEE to obtain plastics with high concentration in FRP, or directly with pyrolysis companies in Europe to obtain char with high content in antimony.

Campine will investigate the combination of LIFE PlasPLUS antimony recovery route with alternative chemical recovery route, as in the PLAST2bCLEANED project.

Activities #7: further research & development.

Research & development activities will continue on:

- Separating and purifying additional thermoplastics.
- Showcasing the upcycling in other end use cases and/or other markets,
- Developping the LCA, carbon footprint and traceability indicators with relevant stakeholders- as standfardisation is a key.
- Develop further (TRL 7) multi-material robotized PickIT sorting to extract in one pass PCBs and FRP from complex plastics waste mixtures.
- Optimize antimony recovery route, e.g. combine with chemical reccyling technologies.



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