Recycling Strategies for Bioplastics: What's next?

Chiara Bearzotti

Berlin, 9 December 2024

europeanbioplastics

EBC24

European Bioplastics Conference

europeanbioplastics

Side Event / Workshop

Recycling strategies for bioplastics: what's next?

Novel approaches in recyling and upcycling bioplastics

9 December, 5 - 8 pm CET
including networking reception

BIOSUPPACK ReBioCycle moBIOS BIOMAC PROSPER

Bio-based Industries Consortium BBI JU Circular Bio-based Europe Co-funded by the European Union Horizon 2020 European Union Funding for Research & Innovation

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Goals

•Offer insights into the latest research and innovative developments, accessing the preliminary results of the EU-funded projects BIOMAC and BioSupPack

•Share the plans of three recently started EU-funded projects, MoeBIOS, ReBioCycle and PROSPER, on novel and improved bioplastic recycling technologies

•Provide inputs on challenges and contribute to advancing research and innovation and market applicability in the field Explore potential partnerships with the experts of these five projects via speed dating

Agenda

Welcome

02

Improving waste management of biobased plastics and the upcycling in packaging, textile and agriculture sectors, Miriam Lorenzo Navarro (ITENE), MoeBIOS

ReBioCycle: A new European blueprint for circular bioplastics upcycling solutions, Jan Pels (Torwash), ReBioCycle

The approach of the PROSPER project, Wouter Post (Wageningen Food & Biobased Research)

Pre-treatment of packaging waste with plasma technology, Chrysa Argeiti and Eva Georgiadou (Agricultural University of Athens), BioSupPack

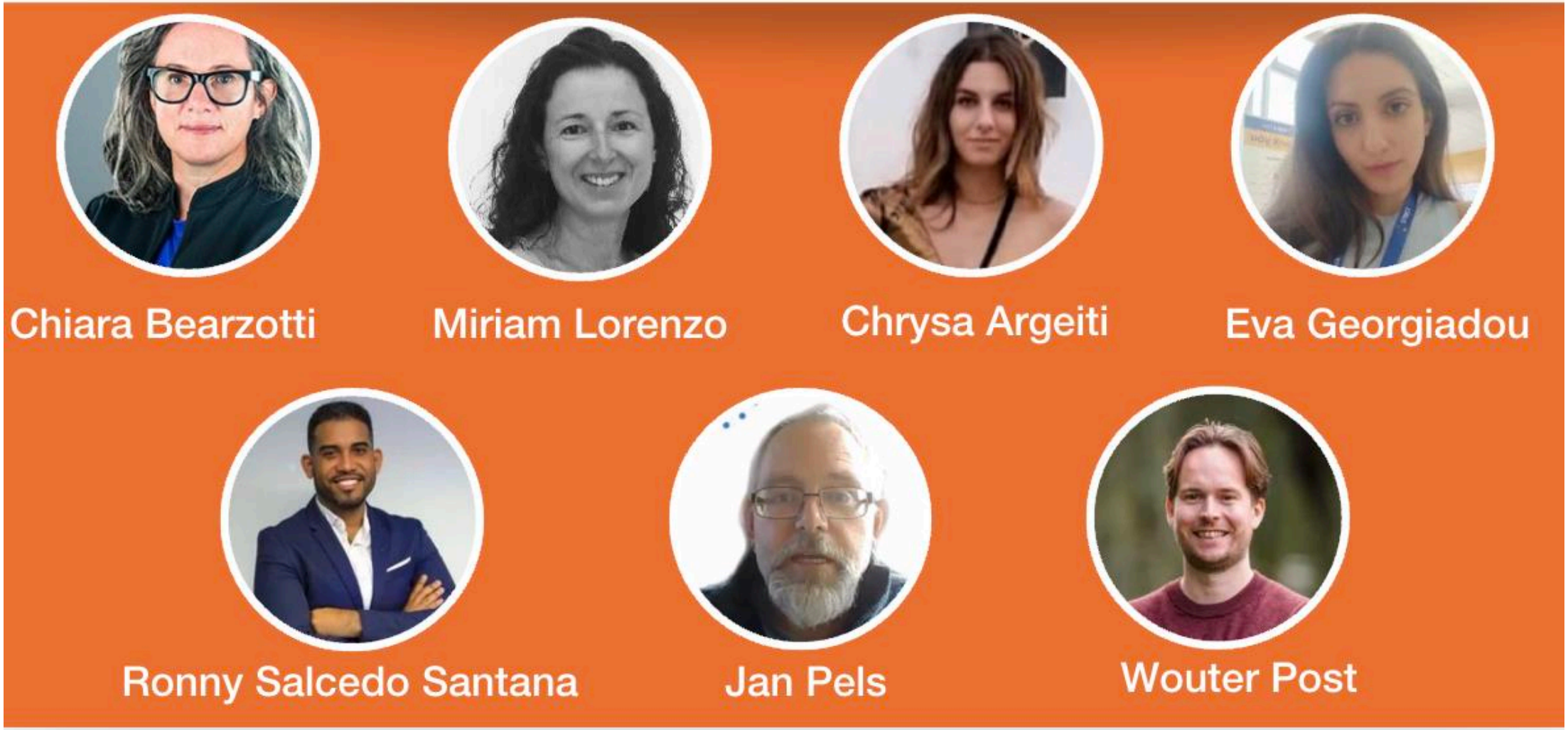
The industrial perspective of recycling, Ronny Salcedo Santana (EVERSIA), BIOMAC

Short Q&A with the speakers

03

Speed dating with the experts: Moving to the tables, change tables every 7 minutes

Recycling Strategies for Bioplastics: What's next?



Horizon 2020
European Union Funding
for Research & Innovation

Circular
Bio-based
Europe
Joint Undertaking

Bio-based Industries
Consortium

Co-funded by
the European Union

Introductory document

https://zenodo.org/records/14231054

End of life Position Paper

by European Bioplatics Task Force

https://www.european-bioplastics.org/end-of-life-options-for-bioplastic-products

About EUBP

Bioplastics are one of the most significant innovations to tackle climate change and to create a resource-efficient circular bioeconomy in Europe.

European Bioplastics (EUBP) is the association representing the interests of the bioplastics industry along the entire value chain in Europe.

EUBP works very closely with bioplastics businesses, EU policy makers, and other key stakeholder groups to ensure a supportive policy and economical framework in Europe for our emerging industry to thrive in.

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The association representing the interests of the bioplastics industry in Europe.

Join us now.

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IMprOving wastE management of BIObased plastics and the upcycling in packaging, textile and agriculture sectors

Miriam Lorenzo Navarro- ITENE

Project Coordinator

Berlin 9/12/2024

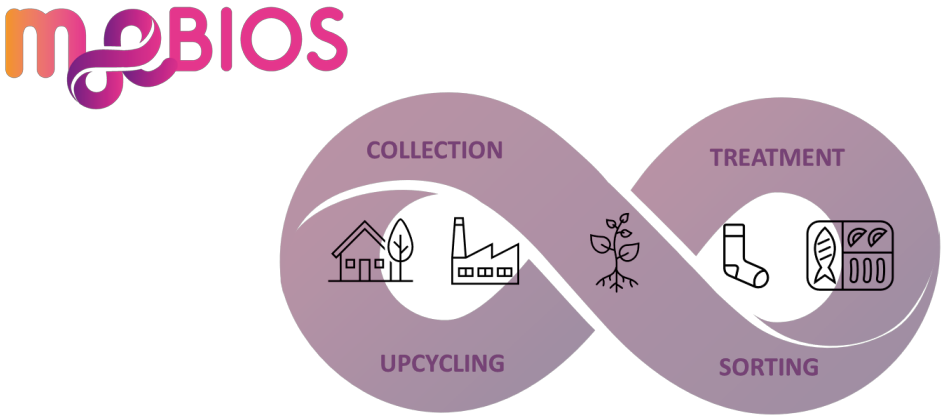
MoeBIOS project has been funded by the EU and the CBE-JU under grant number 101157652.

OBJECTIVE

The MoeBIOs concept :Closing the loop of the BIOs End of Life

MoeBIOS has a mission to **establish circular and sustainable** value chains for bioplastics that will be found in **packaging, textile and agriculture waste streams**: this will involve bioplastic **collection and sorting, recycling with the most efficient techniques** and **further upcycling** into added-value products. MoeBIOS will accompany and support the expected growth of bioplastics in the market by providing effective and upscaled end-of-life solutions.

The overall objective of MoeBIOS is to demonstrate novel recycling routes for bioplastics waste streams (BIOs) along the EoL within 3 value chains, towards new upcycled high-value products



- Decision Support System (DSS)
- Multiactor approach (MAA)
- Safe and Sustainable by Design (SSbD)

Multiactor approach → Waste Managers | Industry | Citizens | Brand-owners | Policy makers | Research

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Key features

- Demonstrating the integration of the bioplastics (**BIO**s) End of Life value chain from collection, recycling, upcycling in Packaging (Spain), Textiles (Italy) and Agriculture (Germany)
- Consortium of 21 partners + 2 Affiliated Entities led by **ITENE** Research Centre
- Waste streams containing **BIOs** as a feedstock
- 3 upcycled demonstrators from developed value chains (packaging, Agriculture and Textile)
- Reduce waste, lower environmental impact, providing a sustainable alternative to fossil resources
- Creation of a novel model for the **BIOs** End of Life in Europe focused in 3 sectors: packaging, textile and agriculture

How the challenge is addressed:

WASTE STREAM VALUECHAIN

PACKAGING WASTE STREAM

AGRICULTURAL WASTE STREAM

TEXTILE WASTE STREAM

Safe and Sustainable by Design - LCA - LCC

COLLECTION	SORTING	TREATMENT	UPCYCLING	VALIDATION END USER
• Waste generation (mapping and characterization) • Waste stream collection • Mixed streams-Multicomponent • Future/social trends • Local authorities engagement	• BIO stream identification • IR - UV • Other high-performance sorting technologies (hyperspectral/chemometrics)	• Best technology selection per polymer/value chain • LCA TCA criteria-Good practices • Targeted polymer/DEMO case • Pretreatment • Upgrading requirements	• Closed loop recycling: r-polymer • Target polymer/DEMO case • Formulation/Target • DSS-digital • SSbD principles?	• Social acceptance • Brand owners involvement • Authorities engagement • LCA TGA& exploitation
WASTE MANAGERS MSW Separate collection	SORTING EXPERTISE MACHINERY PARTNER	Mechanical recycling	VALIDATOR OF R-PRODUCT FOR PACKAGING	BRAND OWNER
WASTE MANAGERS Post-use Post-industrial		Bio-recycling	VALIDATOR OF AGRICULTURE R-PRODUCT MANUFACTURER	BRAND OWNER
WASTE MANAGERS Post-use Post-industrial		Chemical recycling	VALIDATOR OF TEXTILE R-PRODUCT MANUFACTURER	BRAND OWNER
		Thermo-chemical recycling		

C&D&E
Stakeholder engagement
Policymakers
New regulations
Standardization

Decision Support System - Best Practices

Recycling Processes

Sorted Material
(Agriculture, Packaging, Textile)

Pretreatment
Agriculture, Packaging
& Textile

>

- Mechanical Recycling
- Chemical Recycling
- Bio-recycling
- Thermo-chemical recycling

Overall **methodology** per value chain
- ✓ Low TRL: Specialized RTO
- ✓ High TRL: Specialized Partner

Supporting **tools**
- ✓ LCA, LCC, sLCA
- ✓ Support Decision Tool
- ✓ SSbD

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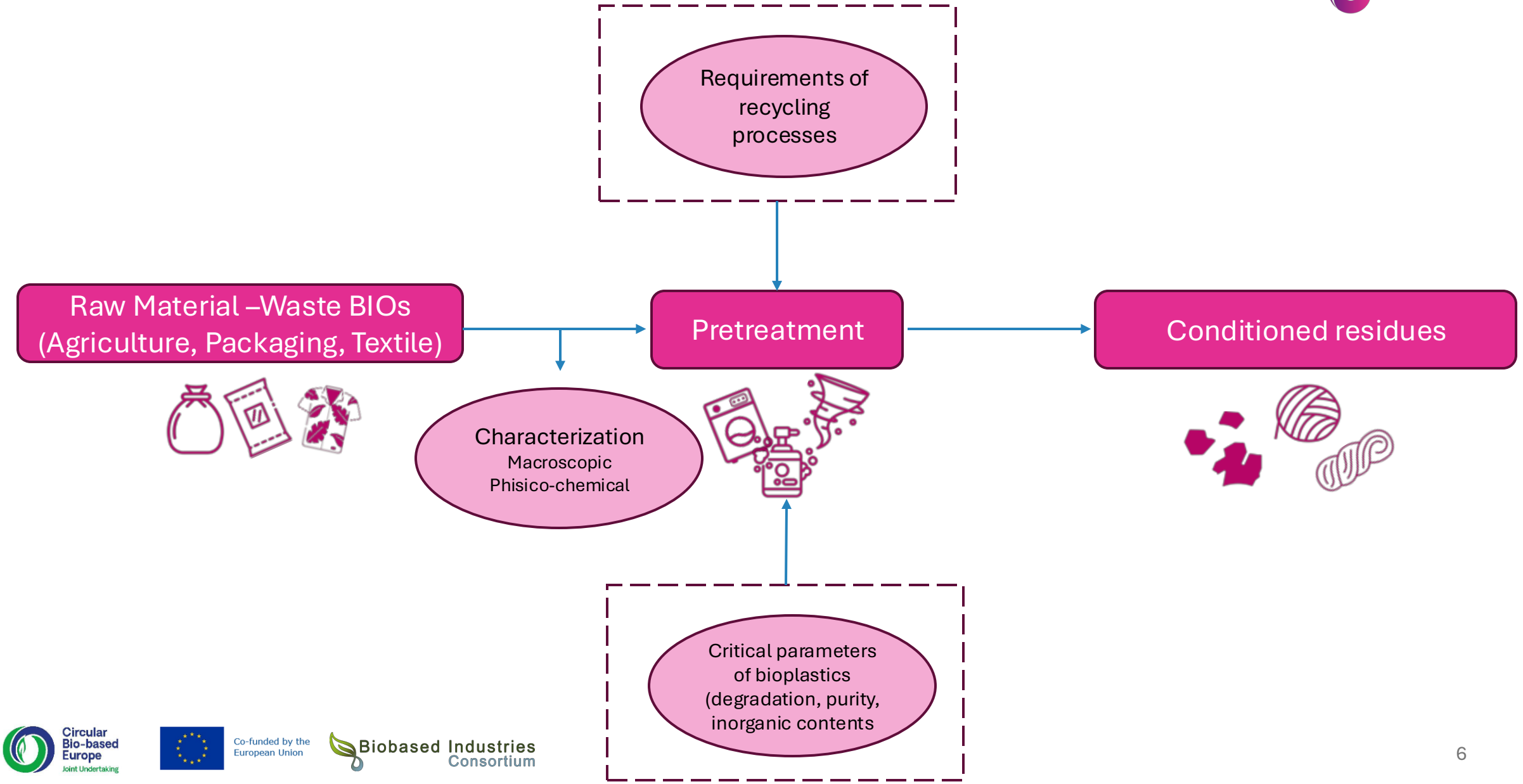
Pretreatments



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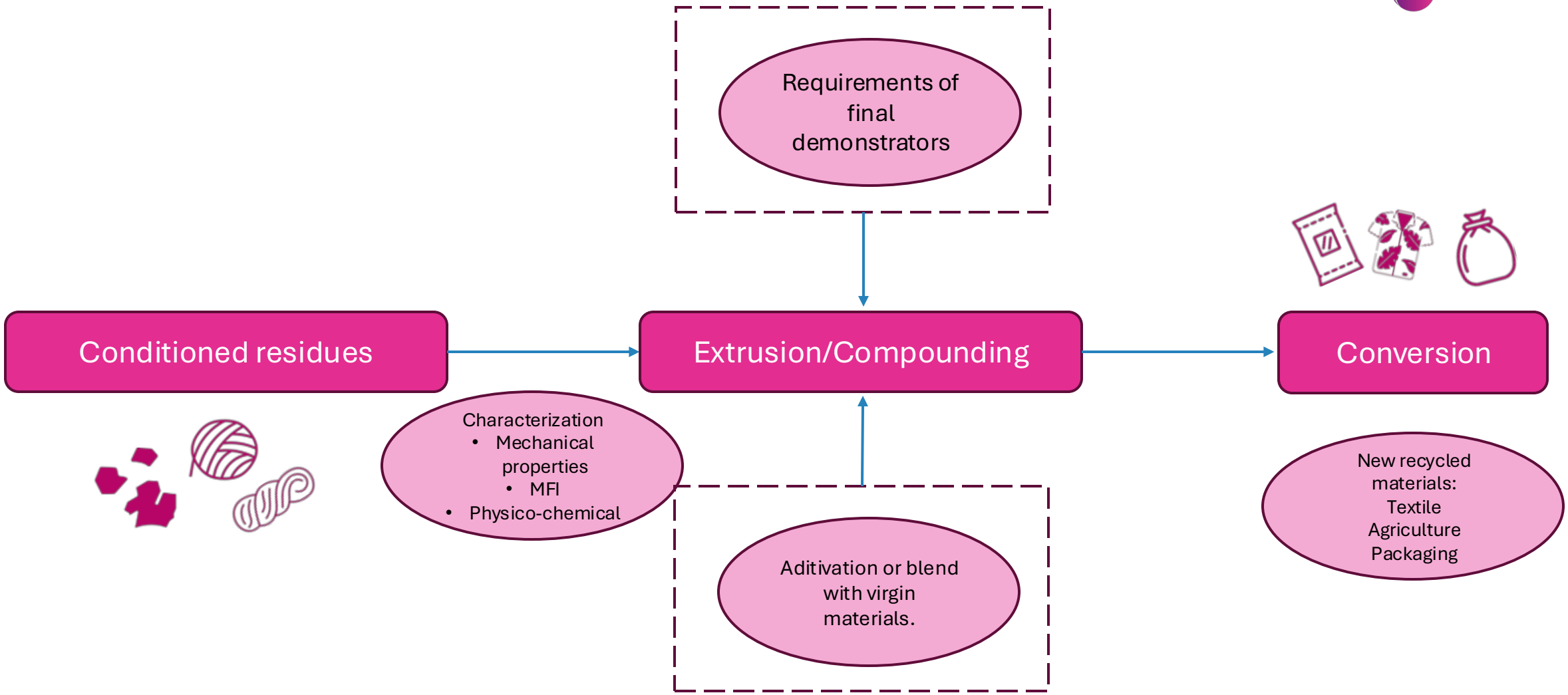
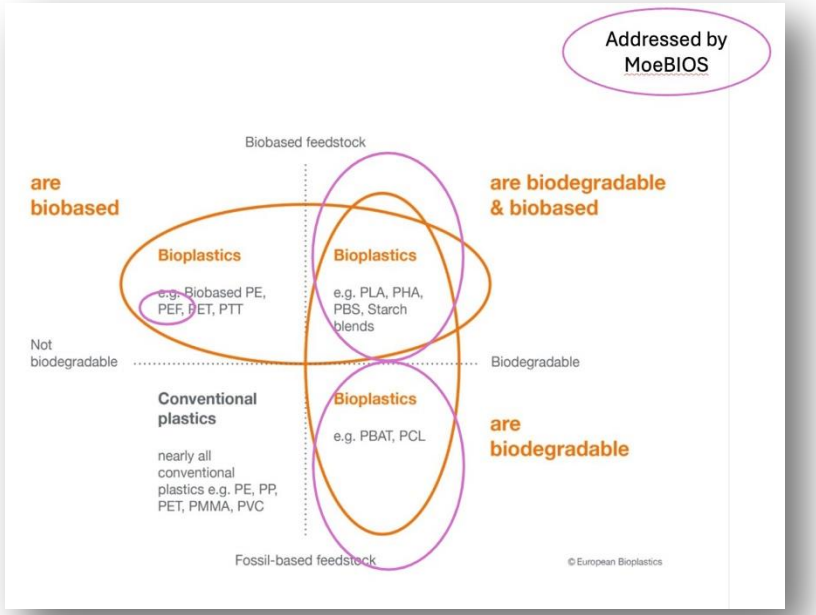
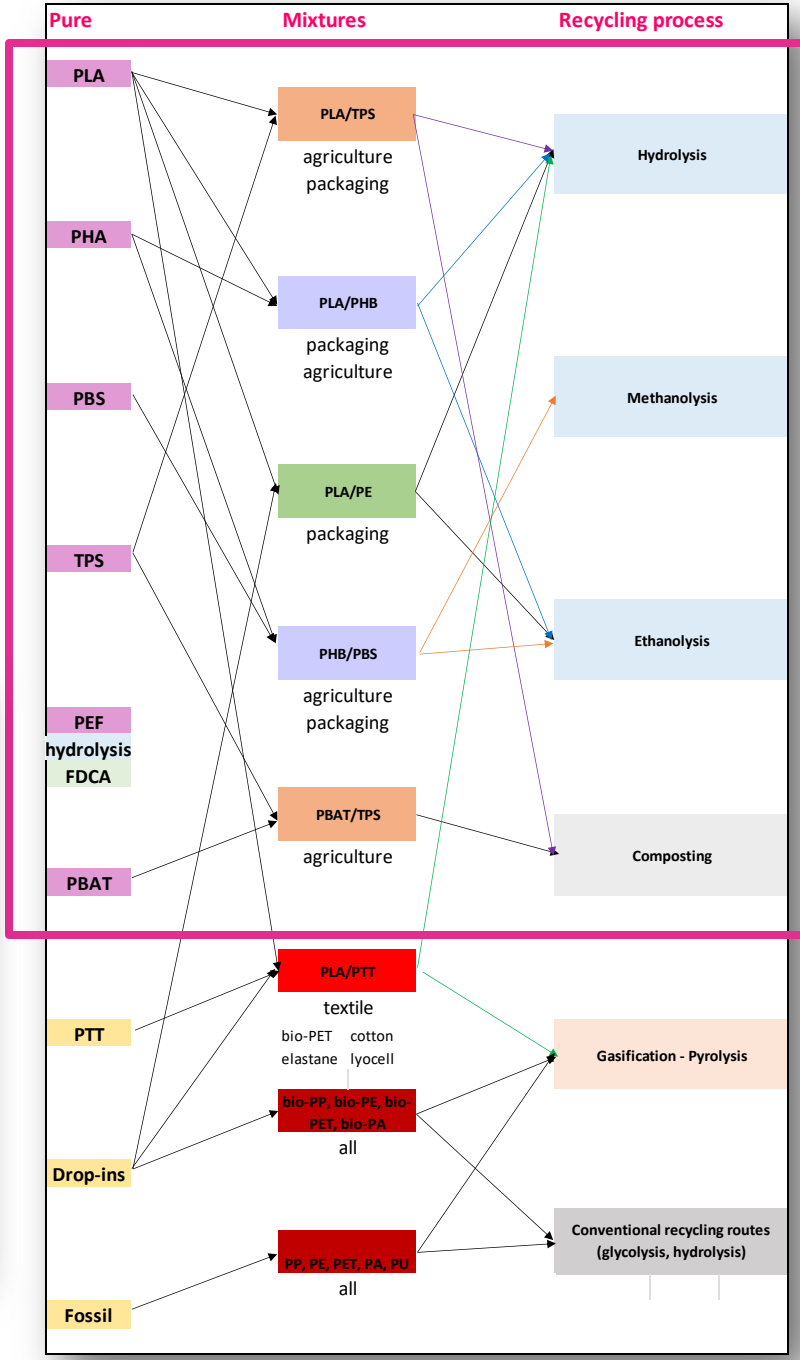
Mechanical-Physical recycling



Recycling

1. **Pure BIOS and blends identification**
   - WP Collection and sorting
   - MoeBIOS validation
2. **State-of-the-art strategies identification**
   - MoeBIOS validation





3. **Recycling Route selection**
   - Chemical
   - Bio
   - Thermo
4. **Route verification**
   - Low TRL experiments→route validation
   - High TRL experiments→best conditions

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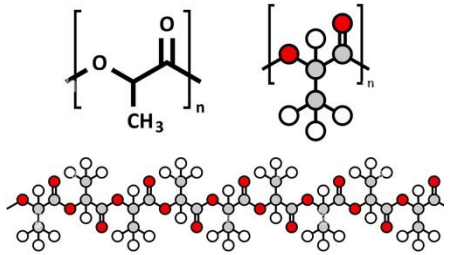
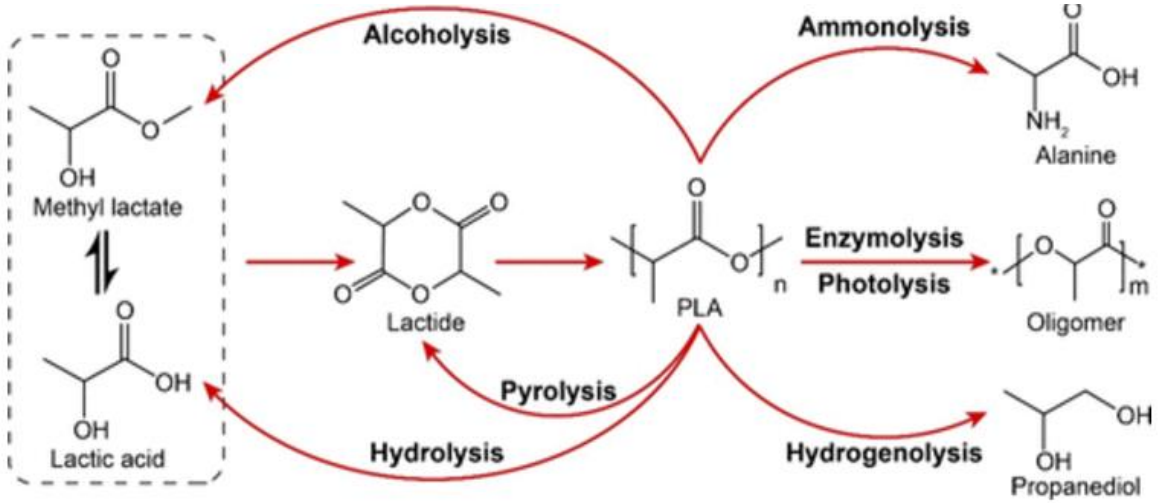
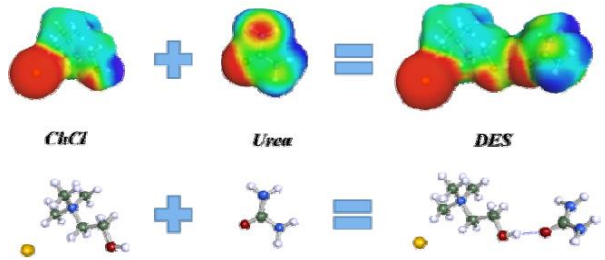
Chemical recycling

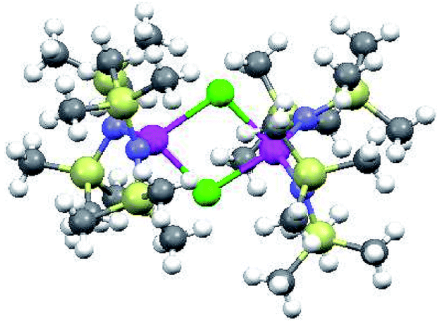
- PLA innovation routes for depolymerization

1. **Hydrolysis** at mild conditions with **selective catalysts**
2. **Alcoholysis** at room temperature with **metal amide catalysts**
3. **Alcoholysis** at mild conditions with **Deep Eutectic Solvents**





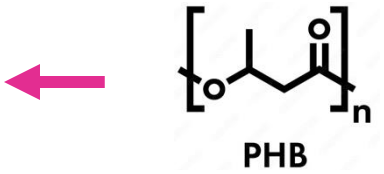




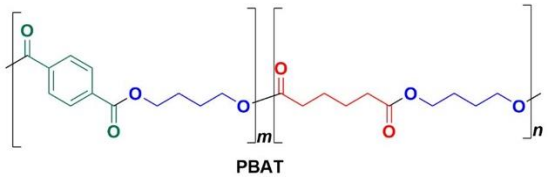
Chemical recycling

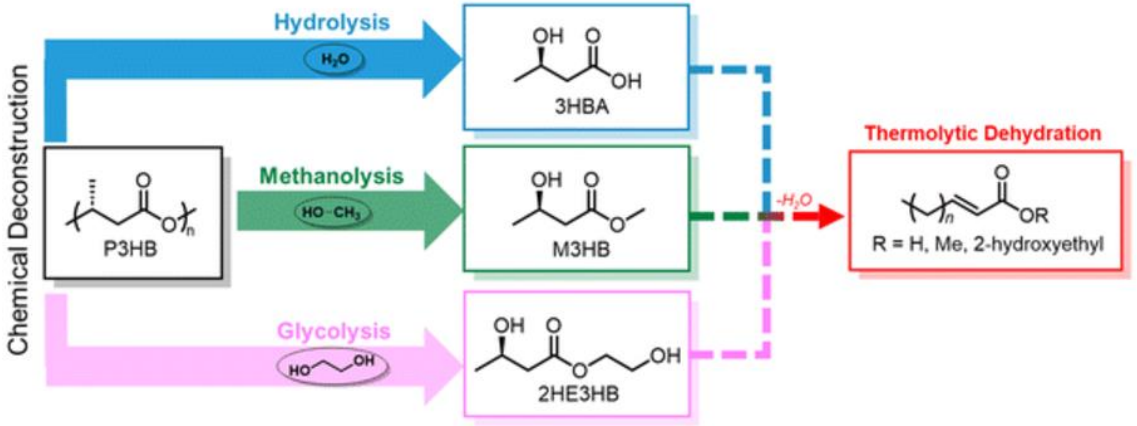
- PHB and PBAT innovation routes for depolymerization

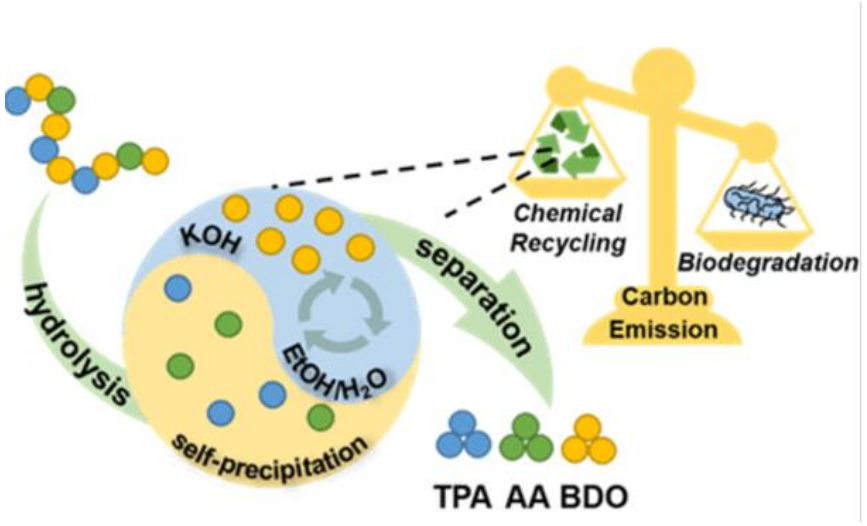
1. **PHB** High temperature **methanolysis** promoting **unsaturated esters**, then hydrogenated to produce methyl esters to be fed to microbes for new PHA.



2. **PBAT** Complete monomer recovery via **high effective hydrolysis and separation** to produce terephtalic acid, adipic acid and 1,4-butanediol.







Bio-recycling

- Methodology

Selection and production of bioplastic degrading enzymes

- Test and **select** potential enzyme candidates for bioplastic compounds degradation
- Develop a protocol for extracellular **enzyme manufacturing**: overproduction of selected enzymes through an efficient expression host and scaling up from 10 L to 300 L working volume.
- Develop a protocol for **enzymes downstream processing** and scaling up from 10 L to 300 L working volume.
- Selection of the **two enzymes with higher efficiency** and versatility for the bio-recycling process.

Development and optimization of the bio-recycling process

- Develop & optimisation of a controlled **enzymatic depolymerization** of single and mixed bioplastics suspensions from lab to pilot scale.
- Generation of up-to-1000 L of bioplastic hydrolysates for upcycling and validation activities
- **Downstream processing** for monomer/oligomer enhanced separation and co-products recovery and re-use. Use of standard physicochemical unitary operations.

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Thermochemical recycling

- Methodology

Gasification process

No Recyclable BIOS

NRW

Bioplastics

Operation parameters (**time, temperature, humidity, gas mixture)** needed for the adequate treatment and transformation of Bioplastics into profitable syngas by using the gasification process will be studied.

Gases

CO_2, H_2, CH_4

Analysis and conditioning of the syngas

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Thank you for your attention

https://www.linkedin.com/company/moebios-eu-com

MoeBIOS project has been funded by the EU and the CBE-JU under grant number 101157652.

ReBioCycle

A new European blueprint for circular bioplastics upcycling solutions
presented by Jan R. Pels (TORWASH)

Coordinator of ReBioCycle:
Kevin O'Connor, University College Dublin,
BIOrbic

9 December 2024, Berlin EBC24 side event

ReBioCycle

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Bio-based Industries Consortium

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Motivation

- **Demonstrate biobased biodegradable plastics recycling**
- Increase the TRL to bring recycling closer to the market reality: Integration and scale up (Technology Readiness Level 6/7)
- Hub structure promoting integration
- Generate critical data /evidence
- **Inform Recycling Industry, Policymaking and Society**

ReBioCycle
Is taking a portfolio approach to biobased biodegradable plastics recycling

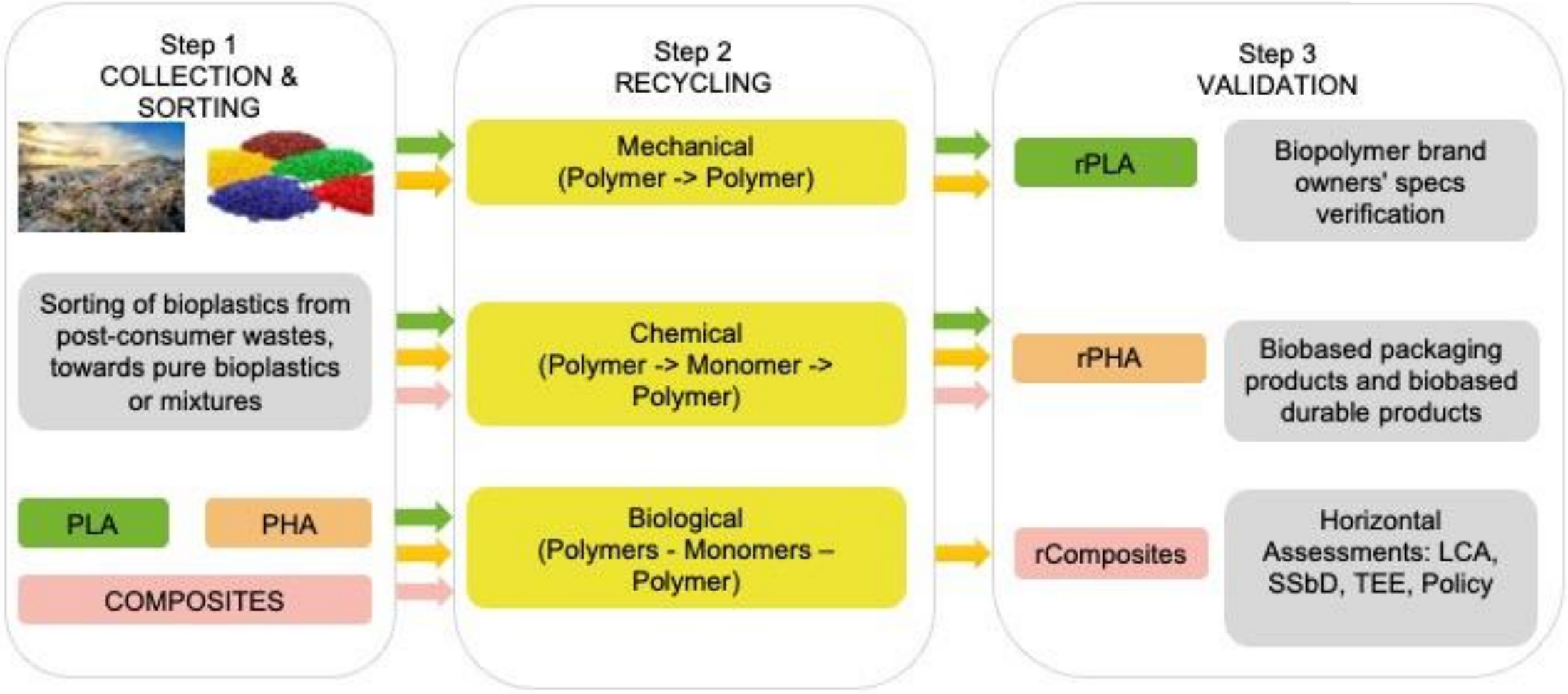
ReBioCycle hubs
Are a critical unit of activity and replication

Data
Will be gathered and used to prepare a blueprint to inform industry and policy

- Innovation Action
- Duration: 1 October 2024-30 September 2028
- Funding: 7.4 M Euro
- Provided by the CBE (Horizon Europe)

Three-step Approach

ReBioCycle



(Too) Many Tech Options

ReBioCycle

- 3 biodegradable plastics: PLA, PHA and composites
- 4 technologies: mechanical, chemical, enzymatic, microbial
- 3 hubs: Dutch, Italian, Spanish
- 3 x 4 x 3 = 36 combinations

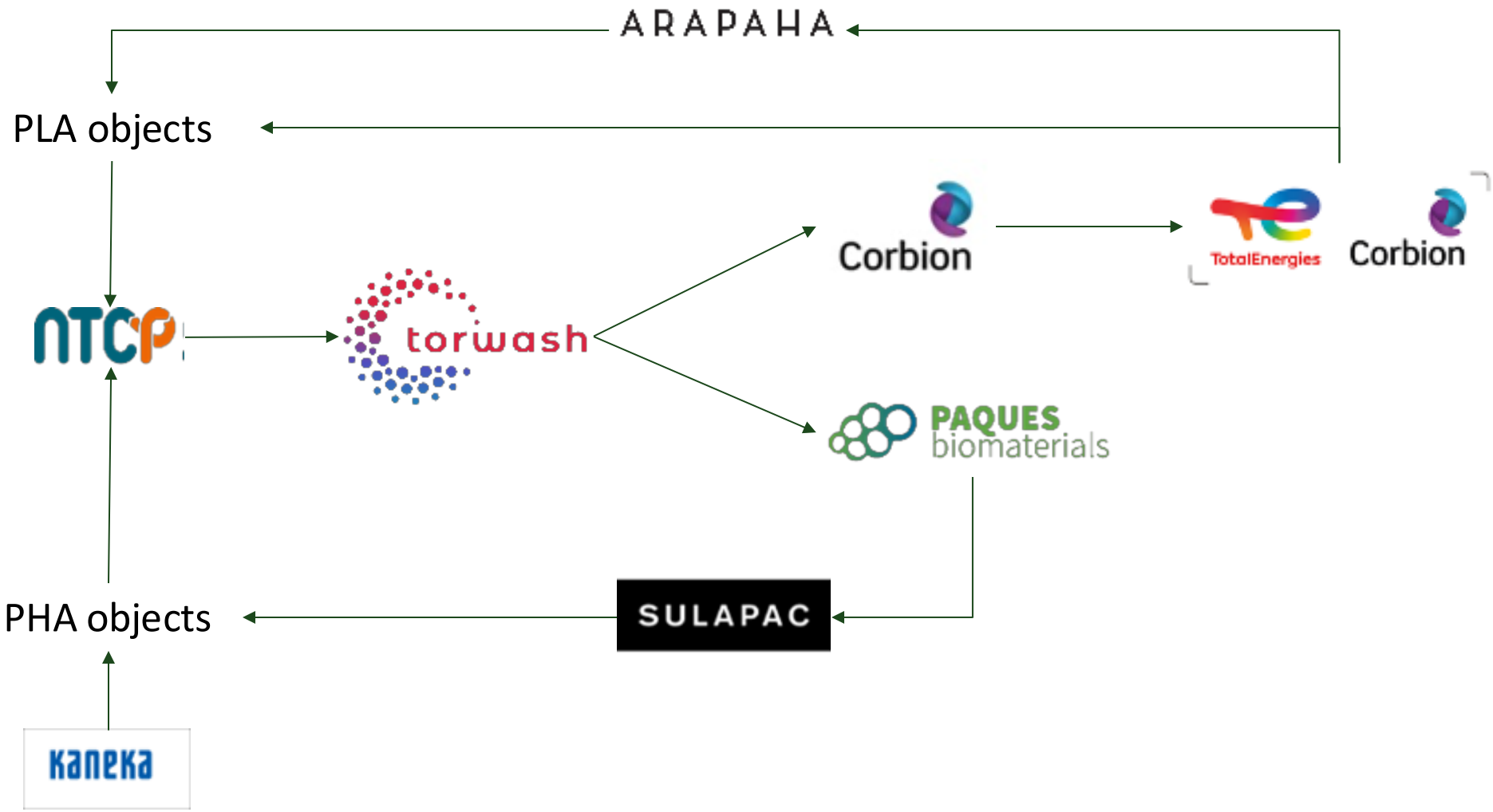
Hub	NL			IT			ES / IE		
	PLA	PHA	Composites	PLA	PHA	Composites	PLA	PHA	Composites
Mechanical							x	x	
Chemical	x	x	o		o	x		o	
Bio-enzymatic							o	x	o
Bio-microbial	x	x	o				x		x

x = full recycle in the same hub o = interaction between hubs

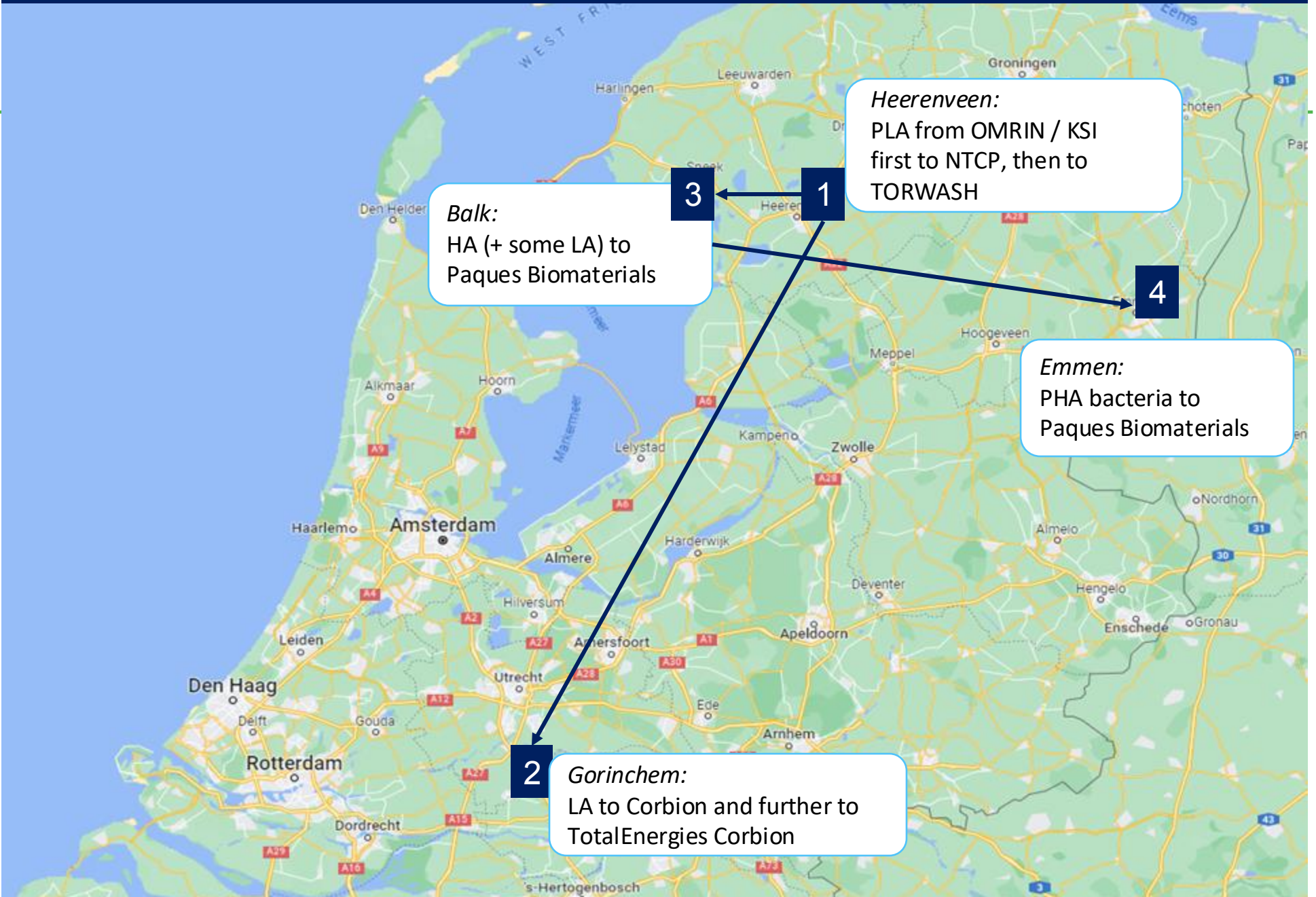
(*) Composites=mixed bio-based biodegradable plastics including blends of different biopolymers

The recycles in the NL Hub

ReBioCycle



NL HUB map



ReBioCycle

TORWASH

TORWASH = hydrolysis of PLA and PHA

- PLA → Lactic Acid at 175°C (patent of DuPont, 1993)
- PHA → Hydroxy Butyrate and Hydroxy Valerate

TORWASH can separate materials

Selective removal from complex objects and compounds

Sequential removal of polymers by manipulating reaction conditions

- PLA, PHBV, PEF, PET, PA, etc. all have specific temperatures
- remaining after treatment: PE, PP, PS, steel, glass, etc.

“Designed-for-Recycling-by-TORWASH”

- Recycling must become integral part of Product Design

Before

After

TNO innovation for life

torwash

Scaling Up

- **Scale-up to mobile unit**
  - Mobile system with 1 m^3 batch reactor
  - → 0.5 – 1 ton per day of shredded PLA, PHA, etc.
  - Dutch Hub in **EU project ReCycleBio** with Corbion, TotalEnergies Corbion, Paques Biomaterials
- **Full Scale** Lactic Acid production from PLA
  - continuous reactor with heat integration
  - → 50.000 ton Lactic Acid per year

Mobile TORWASH installation for sludge

2024-25 Construction of mobile unit, max. 1 ton per day

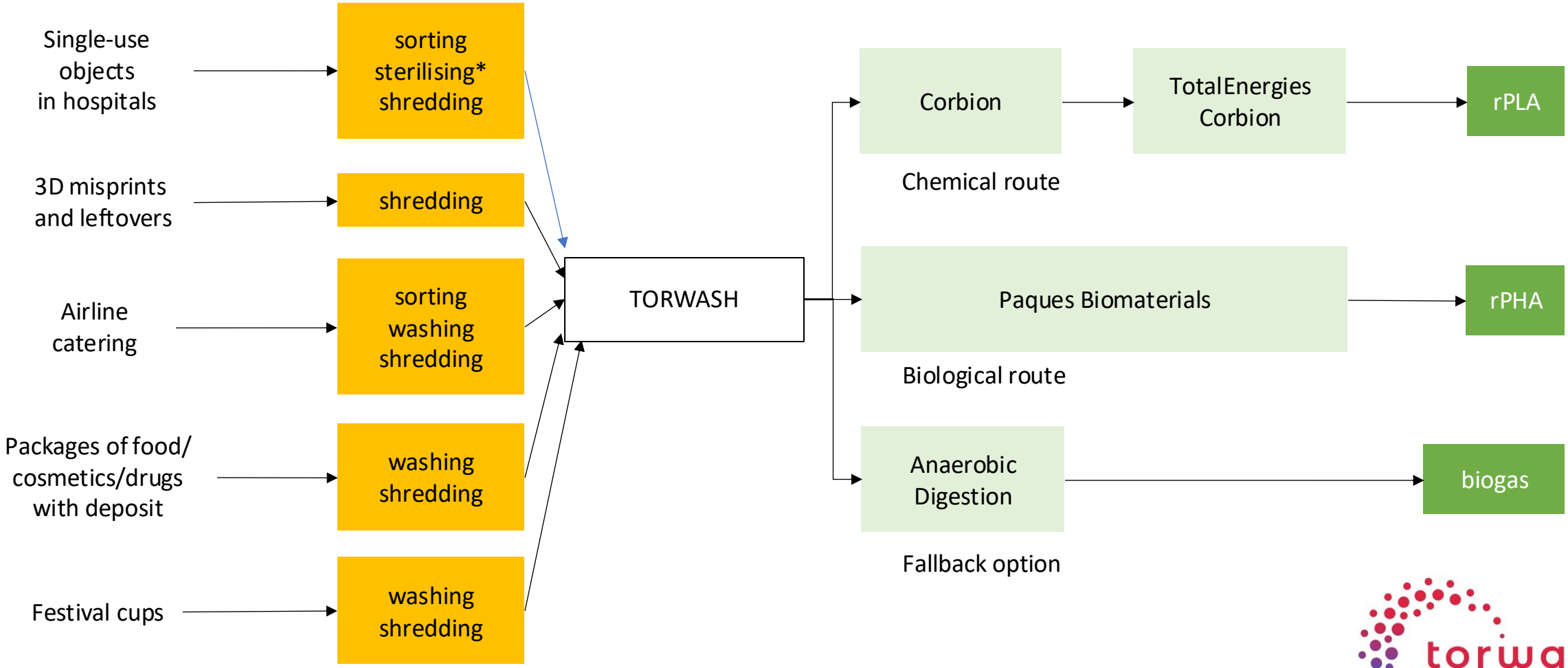
Q3 2025 Processing of few tons PLA, PHA, etc. in ReCycleBio – PLA, PHA objects in municipal waste

Q4 2025 Processing of PLA/PHA material from closed-loop systems – composites

2027 Design of full-scale unit, based on prognosis PLA/PHA volumes 2028-32

torwash

Starting with closed-loop systems



More options: Gift cards / credit cards, Fast Food chains, Returned clothing, Furniture, …

Challenges ReBioCycle addresses

- Technical: real contaminations
- Practical: transporting waste materials
- Legal: recycled material of food grade quality
- Societal: microplastics, food/feed etc.
- Commercial: transition of brand owners

Thank you!

Coordinator: Kevin O'Connor, University College Dublin, BIOrbic
NL Hub leader ReBioCycle: Jan Pels, TORWASH

https://www.linkedin.com/company/rebiocycle

ReBioCycle has received funding from the Circular Bio-based Joint Undertaking (JU) and its members under the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101156032. The JU receives support from the European Union's Horizon Europe research and innovation programme and the Bio-based Industries Consortium

ReBioCycle

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

Co-funded by the European Union

EBC 24 Side Event:
Recycling strategies for bioplastics

9-12-2024

Wouter Post
Wageningen University & Research

PROSPER

Circular Bio-based Europe Joint Undertaking

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Introduction to the PROSPER project

Closing the loop to make bio-based plastics circular

CBE JU contribution: € 7.5 million

Duration: September 2024 – August 2028

Feedstock: used biobased plastics

Main products: sorted and recycled bio-based plastics

PROSPER will demonstrate the techno-economic feasibility of the sorting and recycling of bio-based plastics in 4 actual waste sorting plants in Spain, France and Italy to generate new packaging from the recycled bio-based plastics

PROSPER

Our partners

PROSPER

Wageningen University & Research

Contract Research Organisation

Governments, NGO's, institutional funders, industrial companies

Highly engaged, proficient experts

World-class facilities and laboratories

Wageningen University & Research



From waste plastics via sorting and mechanical recycling to granulates and products

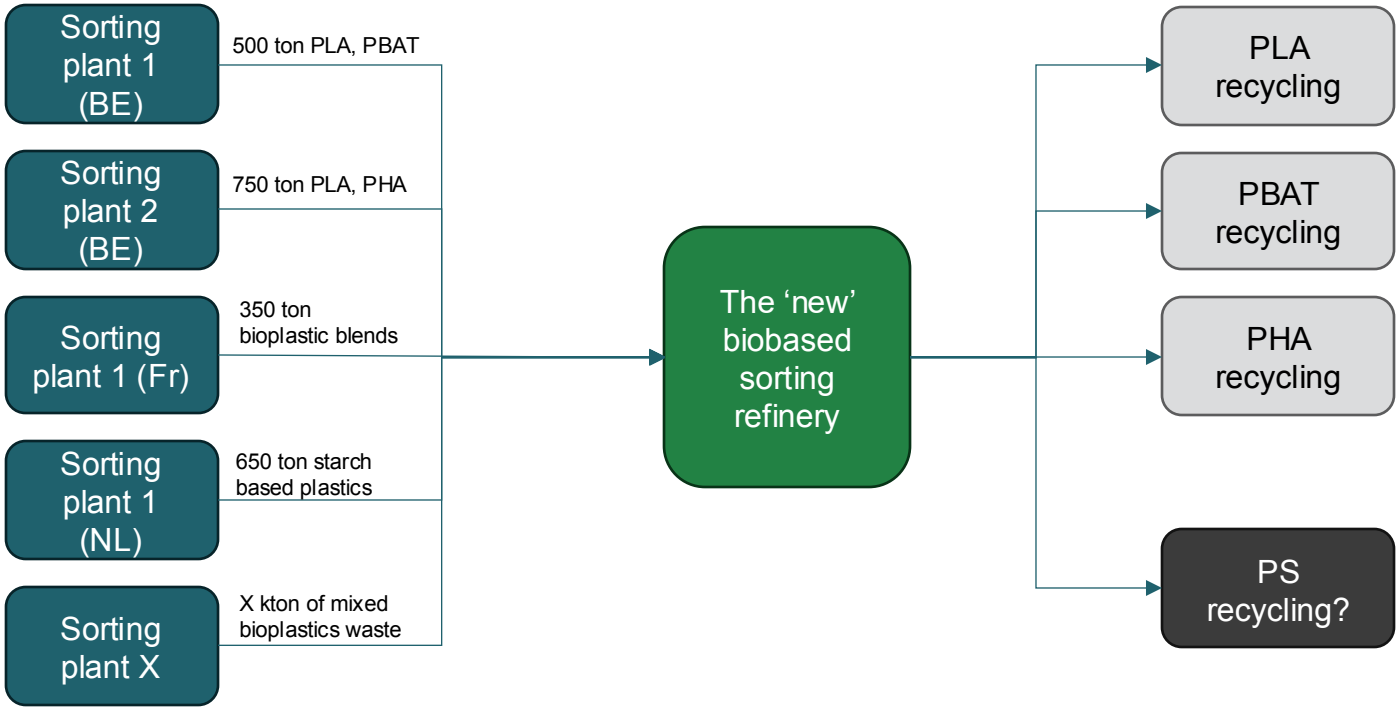


From biodegradable plastics to compounds and products to biodegradation testing

PROSPER

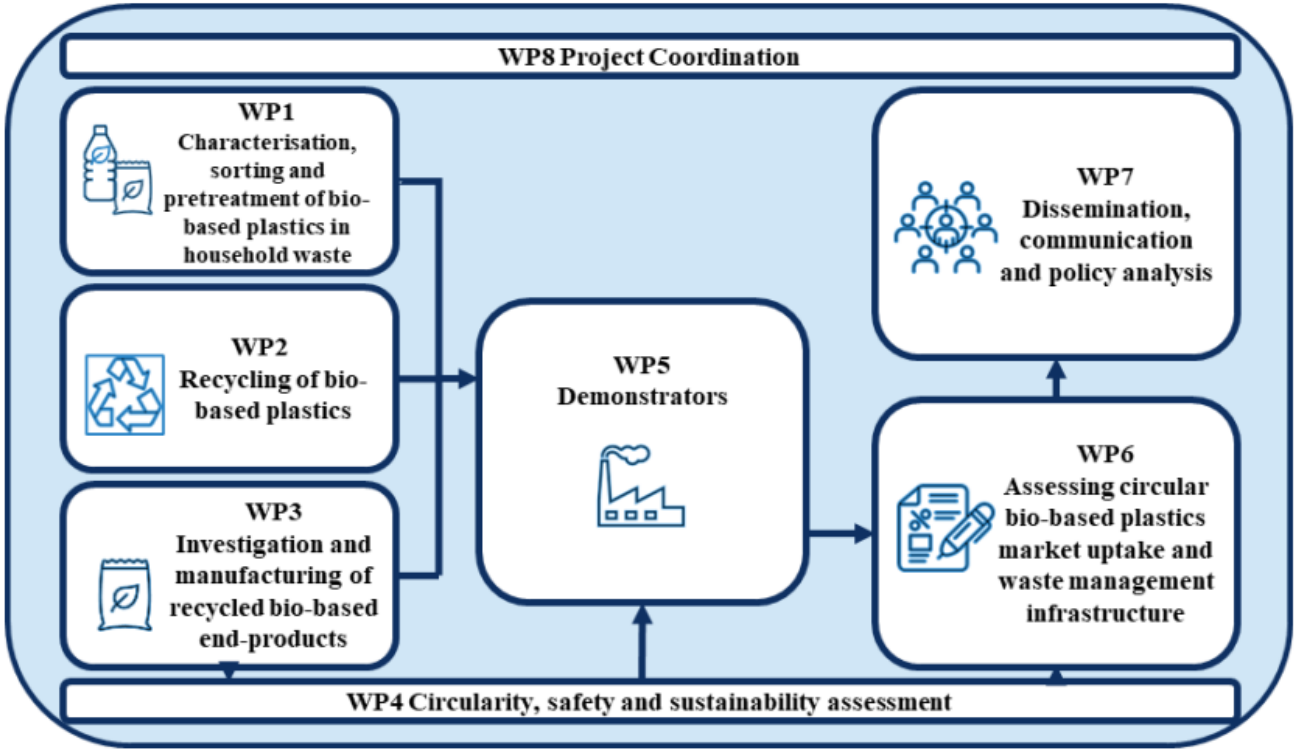
PROSPER Vision

- Plastic waste that does not get sorted, will not be recycled
- Plastic products without scale, will not get sorted



PROSPER approach

PROSPER project setup



3 European Recyling Pilots

Italian Pilot

The Italian pilot demonstrating innovative biobased plastics will be managed by A2A and A2A Ambiente, with the cooperation of Novamont SpA.

In Italy, the biobased plastic waste sorted in A2A's waste sorting plant will be tested for large scale pretreatment and chemical recycling (depolymerization) by Novamont SpA.

Spanish Pilot

The Spanish pilot will be managed by FCCMA

In Spain, the biobased plastic waste sorted by FCCMA will be delivered to ENVICO to demonstrate the pretreatment and mechanical recycling through extrusion, handling various plastic grades at scale.

French Pilot

The French counterpart will be managed by SUEZ.

In France, Futerro will demonstrate a depolymerization process of sorted waste PLA.

Further, chemical depolymerization and downstream processing technologies for targeted bio-based plastic waste will be demonstrated.

PROSPER

Conclusion and outlook

- Due to the relatively small volumes bio-based plastics are currently not being recycled, which blocks their scale-up.
- PROSPER aims to think out of the box at system level to get bioplastics out of the catch 22
- Strong consortium with actors all over the value chain
- Not only solving the bioplastic recycling issue, but the question: *'how to set up cost-competitive sorting and recycling schemes for minor polymer fractions in packaging'?*
- Biobased and biodegradable plastics have all potential to be circular
- PROPSER will demonstrate in 3 EU pilots the proper sorting, recycling and reuse in new plastic packaging products

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Thank you.

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PROSPER

Pretreatment of packaging waste with plasma technology

Chrysanthi Argeiti, Eva Georgiadou

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LinkedIn

Group on Bioprocess Engineering & Circular bioeconomy

EBC24 Side Event: Recycling strategies for bioplastics

9 December 2024

EBC24 European Bioplastics Conference

Research interests

Agricultural University of Athens

Department of Food Science and Human Nutrition

Group of Food Bioprocesses Engineering & Circular Bioeconomy

https://becb.aua.gr/

Group of Bioprocess engineering & circular bioeconomy

Renewable resou

Agro-industrial residu
Organic fraction of mun
solid waste
Food waste

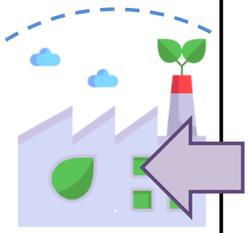
EoL recycling of biobased packaging

Thermochemical/ Enzymatic degradation

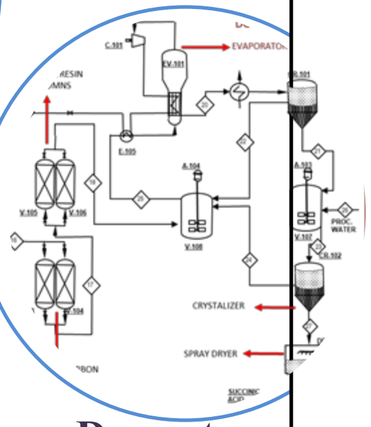
Fermentation

PHAs

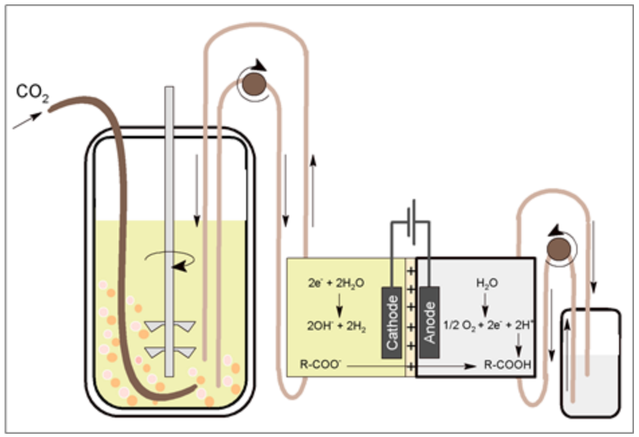
Pure fermentation products



Upgrade of convent lignocellulosic biorefineries



Downstream

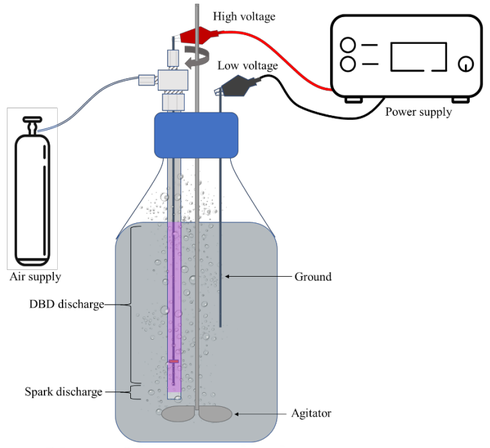


Electrochemical membrane extraction

Novel electrification technologies

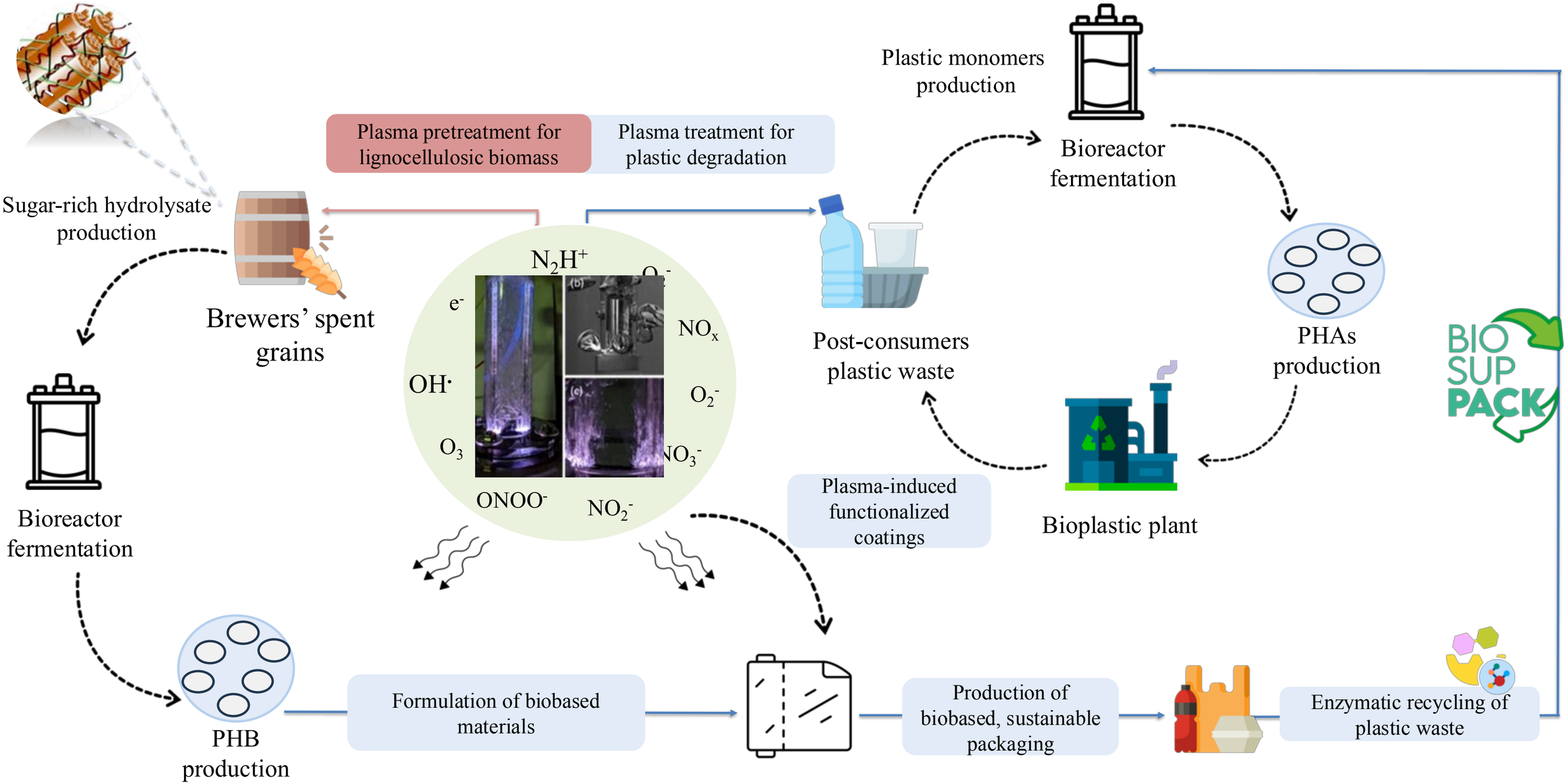
Can be applied in:

- Biomass pretreatment
- Fermentation
- Downstream separation and purification
- Degradation of final product



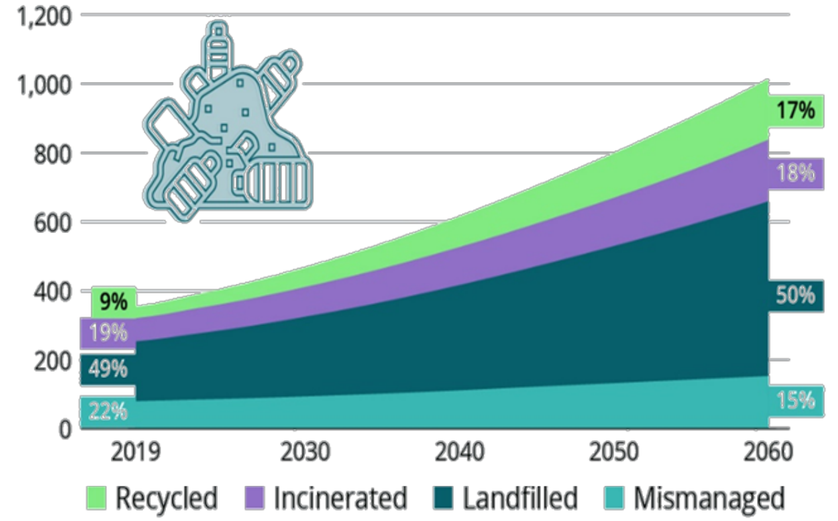
Non-thermal plasma

Demonstrative process for the production and enzymatic recycling of environmentally safe, superior and versatile PHA-based rigid packaging solutions by plasma integration in the value chain



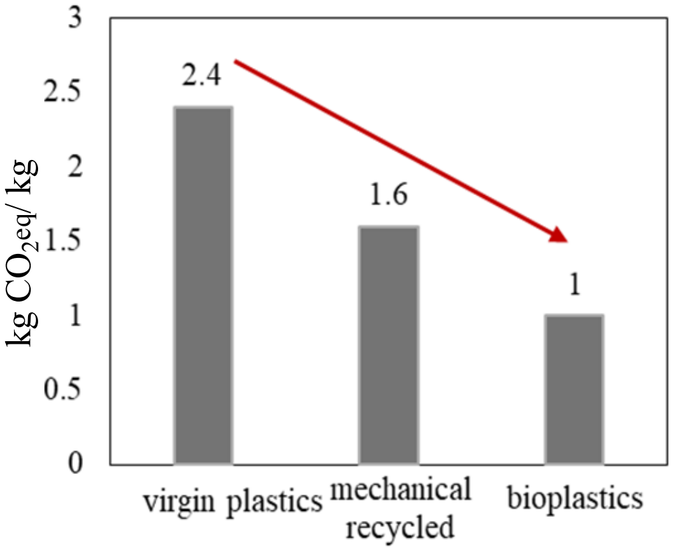
The plastic problem - Identifying the loop in the value chain

Projection of plastic waste management in EU



1-2.7 t CO_2-eq/ t polymer could be saved if all plastics were mechanically recycled by design

Production of plastics/bioplastics



Energy consumption

Plastics production: 80 MJ/kg

Bioplastics production 30-40 MJ/kg

Disposal of plastics/bioplastics

Plastics

incineration

2.9 t CO_2- eq / t incinerated plastic

Landfill

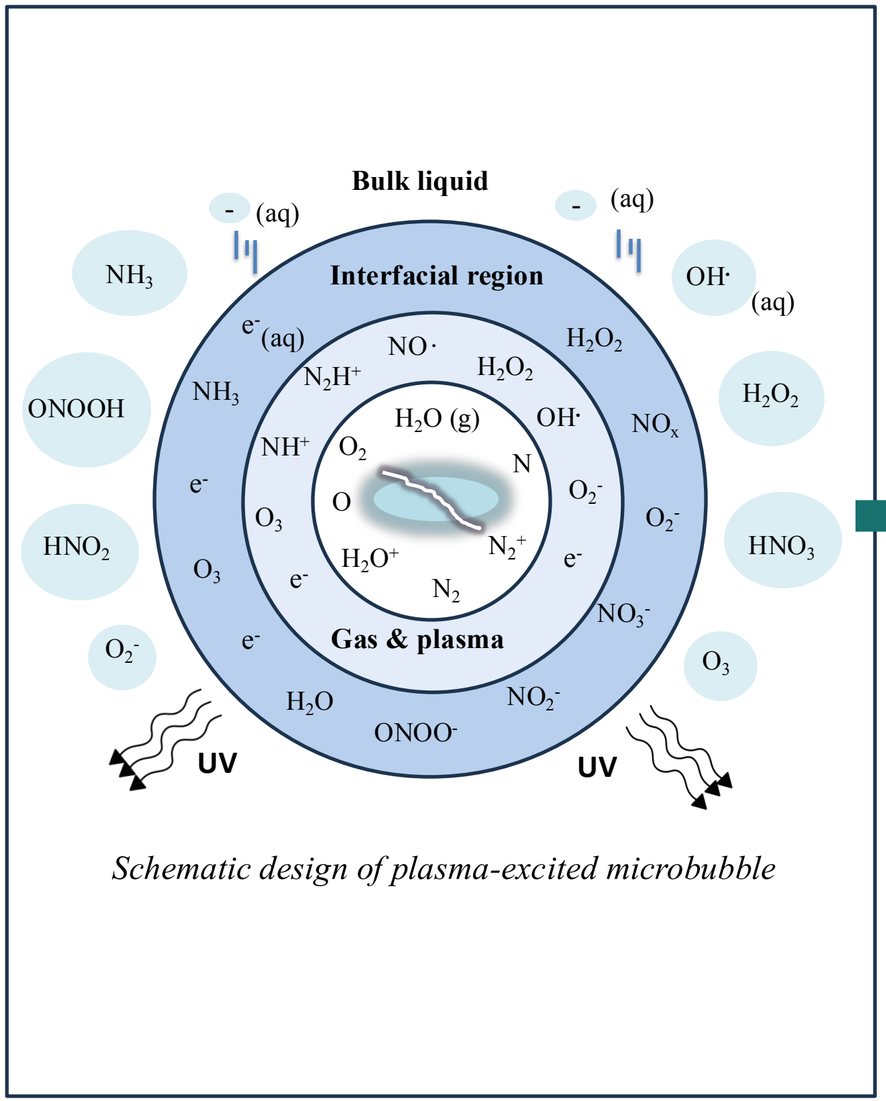
254 g of CO_2 / t plastic and microplastic generation

Bioplastics

Methane release from anaerobic digestion

Microplastics and contaminants release

Non-thermal plasma principles



Schematic design of plasma-excited microbubble

NTP generation: A gas is subjected to an electrical field at atmospheric pressure, leading to its ionization

Advantages of plasma treatment against thermochemical treatment:

A. Improved resource and energy efficiency

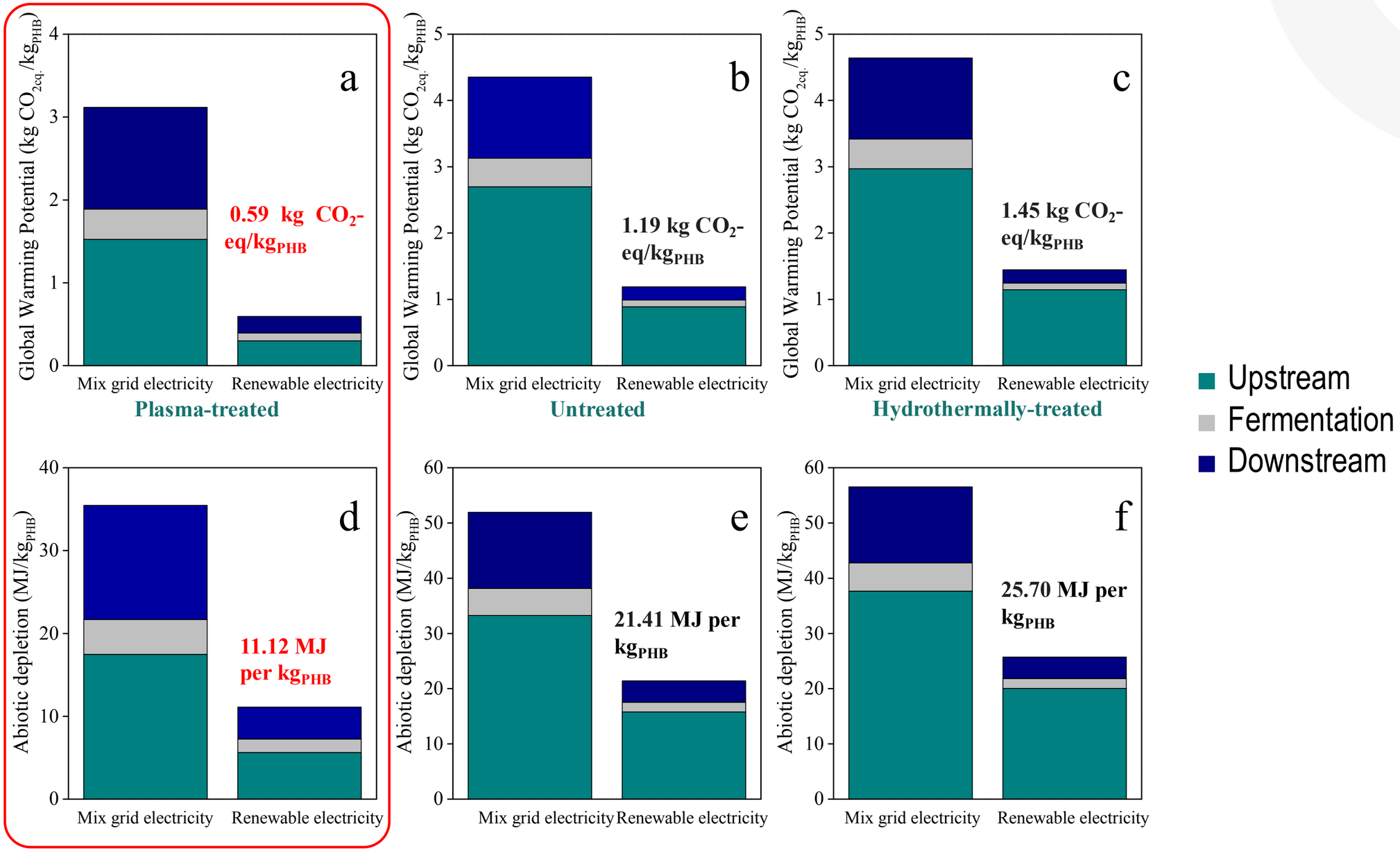
B. Utilization of renewable energy sources

C. Elimination of chemicals and solvents

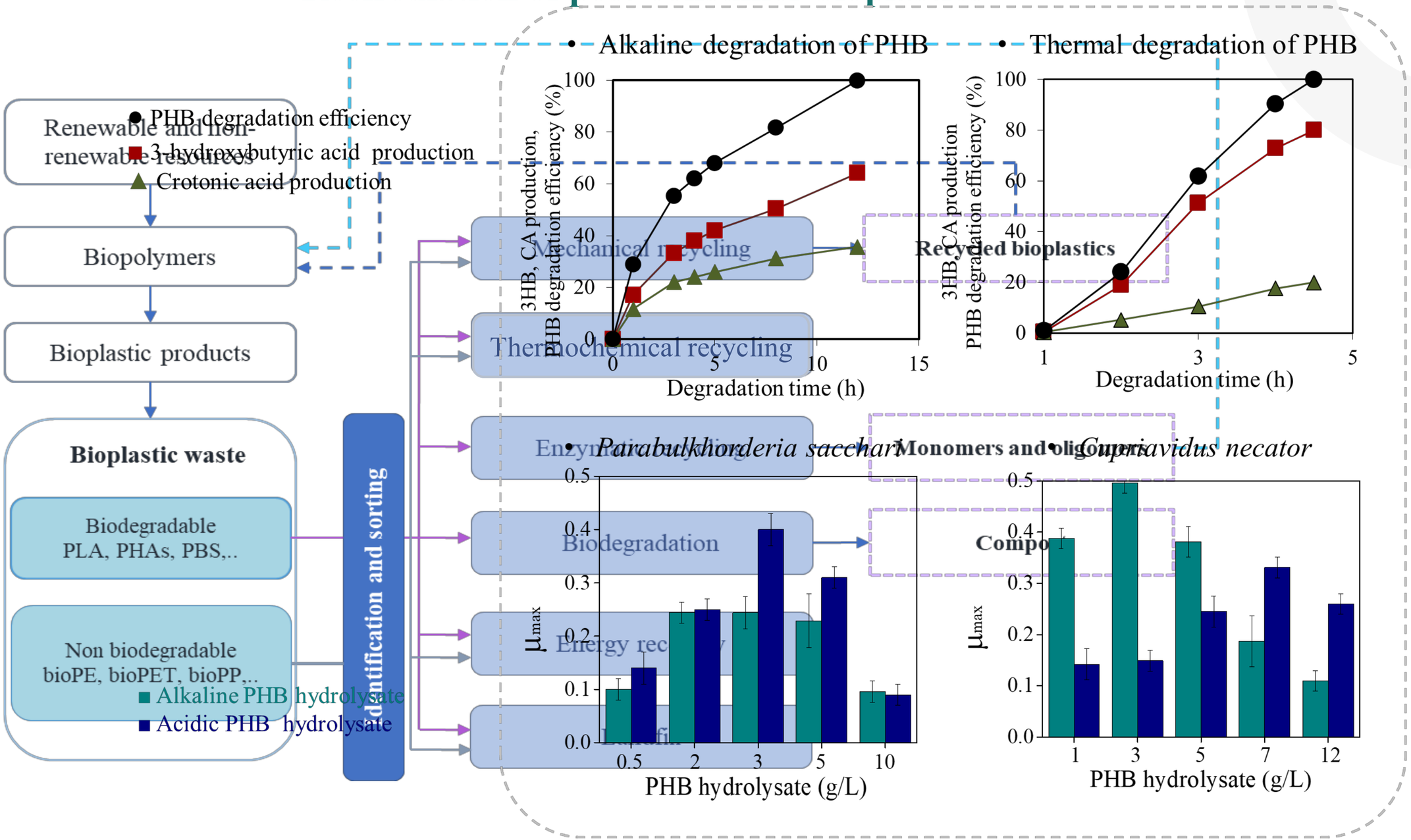
D. Processing at ambient temperatures and pressures

E. Improved sustainability and circular by design processing

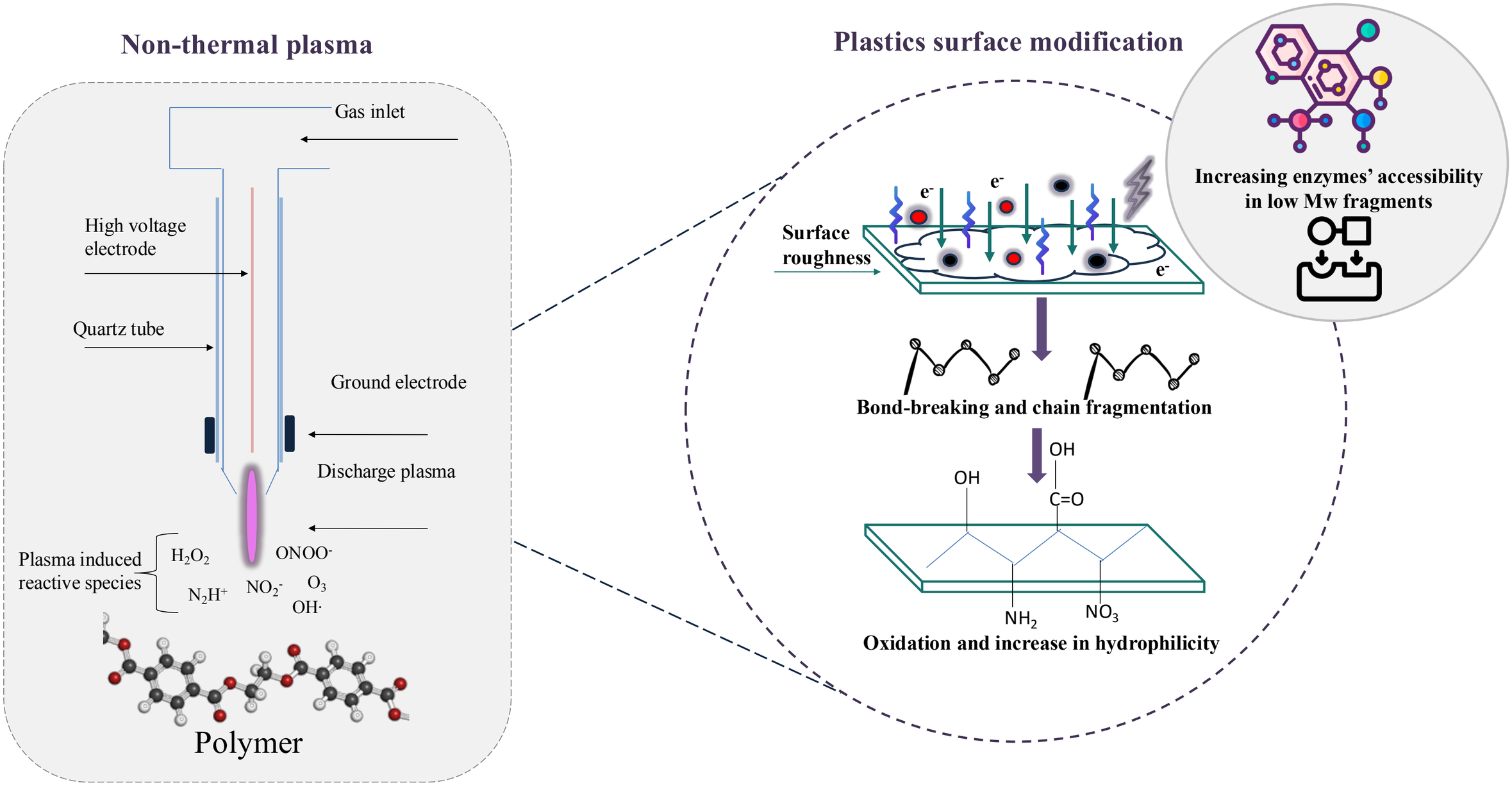
Electrified-based biorefinery of Brewers' Spent Grain for PHB production



Recirculation of post-consumer bioplastics

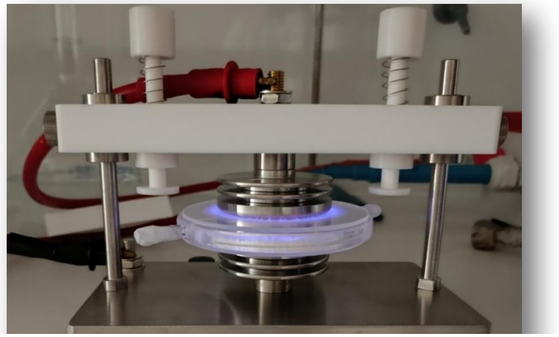


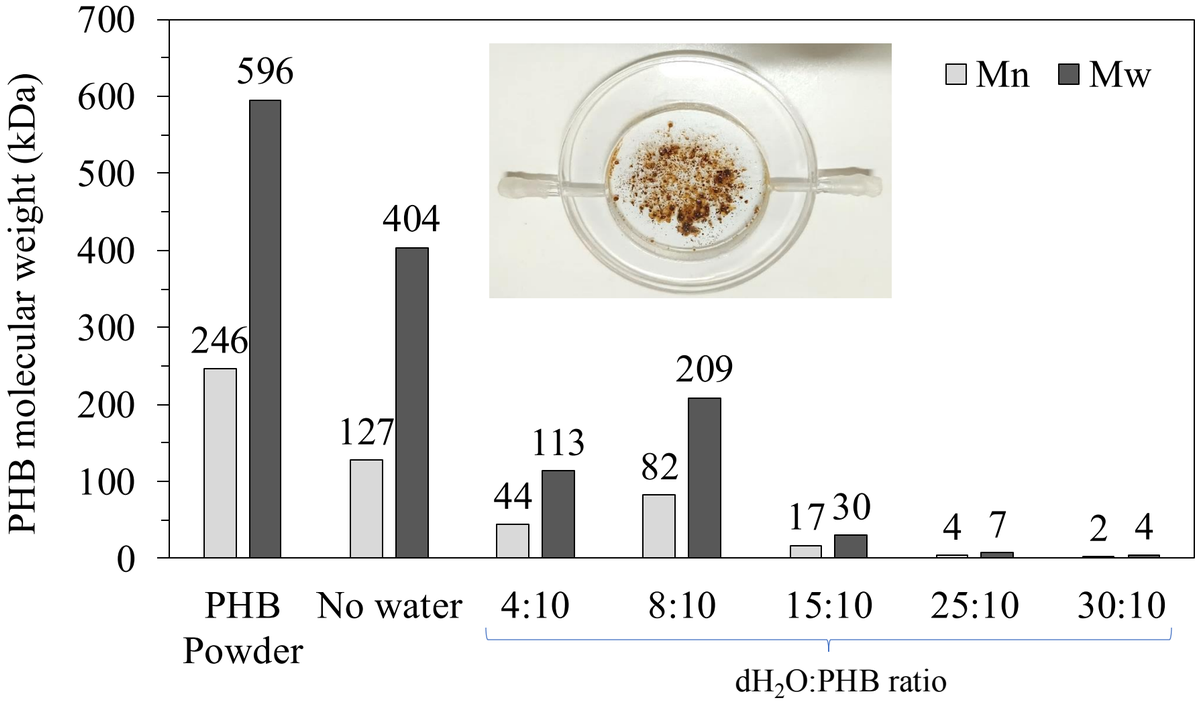
Mechanism of plasma-induced plastic degradation

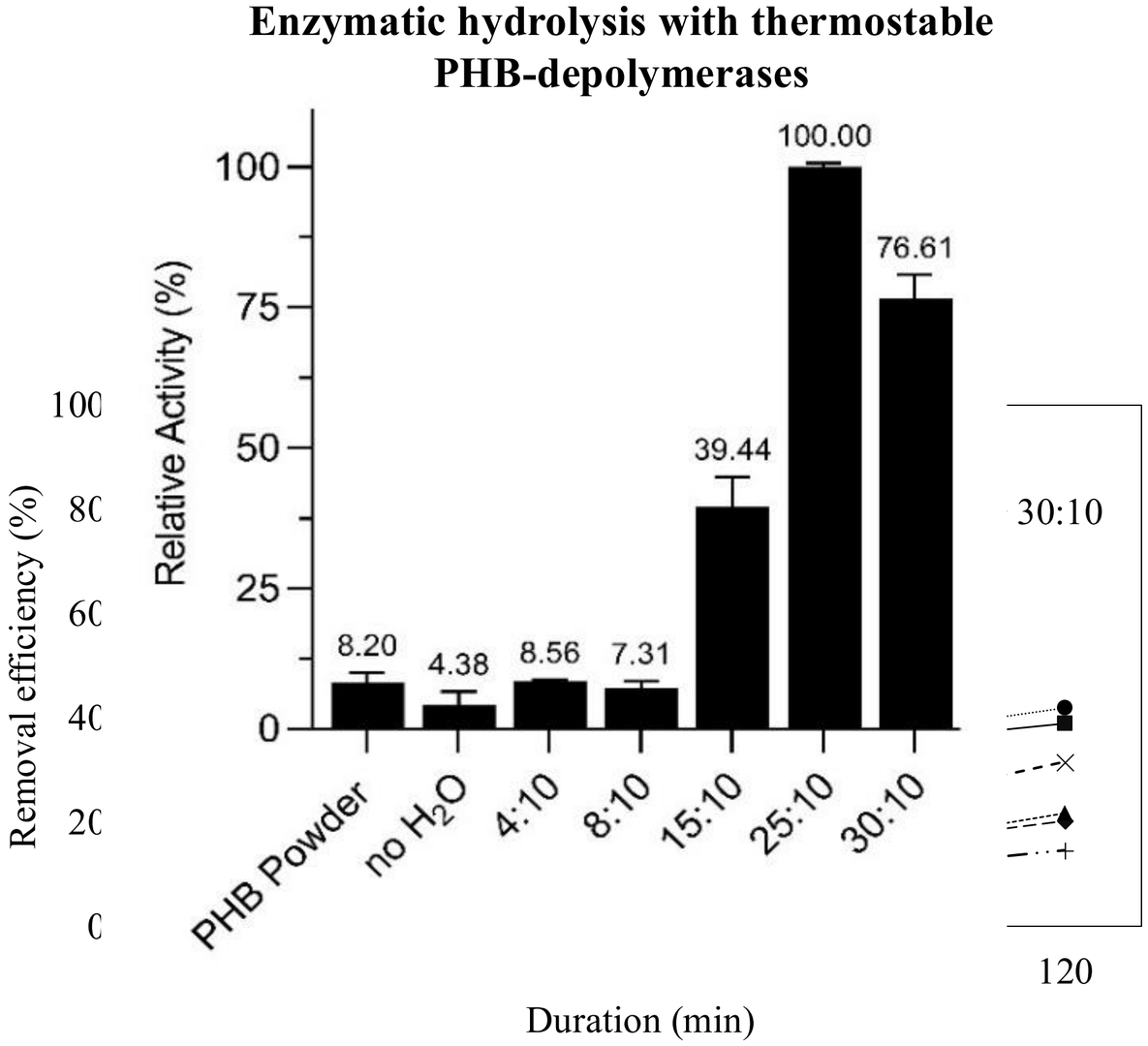


Pre-treatment of biobased materials by plate-to-plate plasma reactor

PHB powder

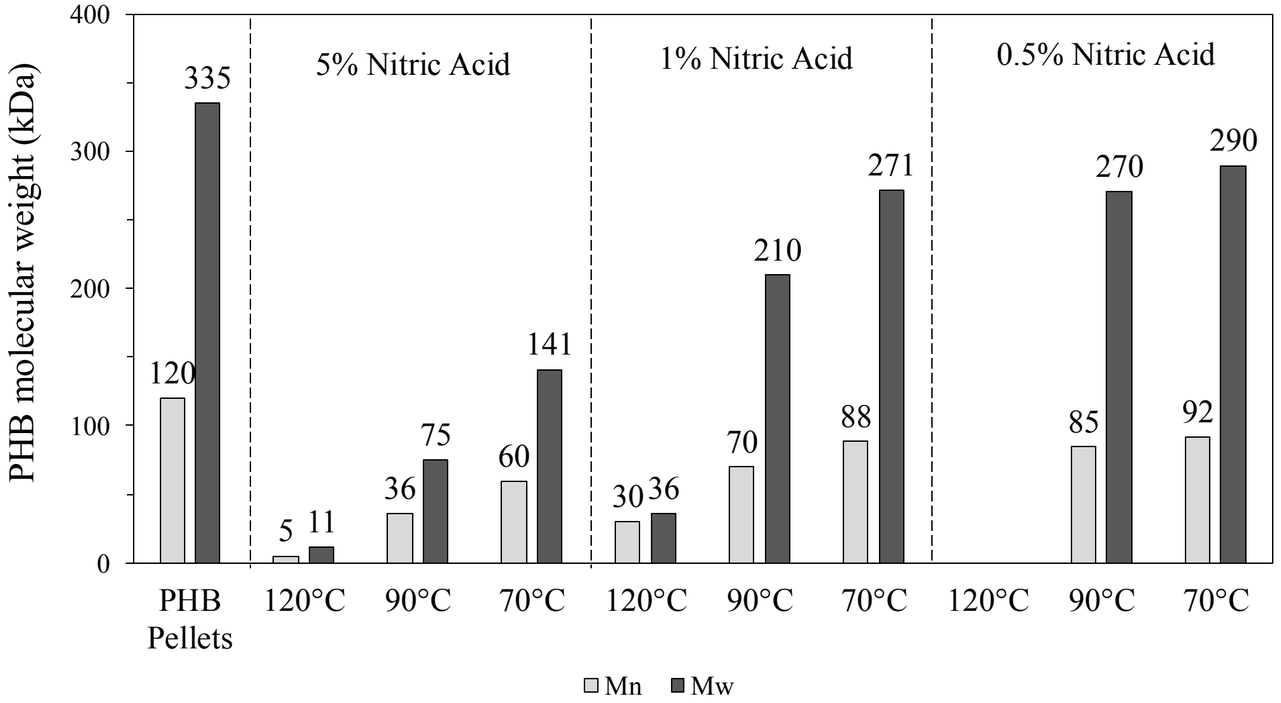




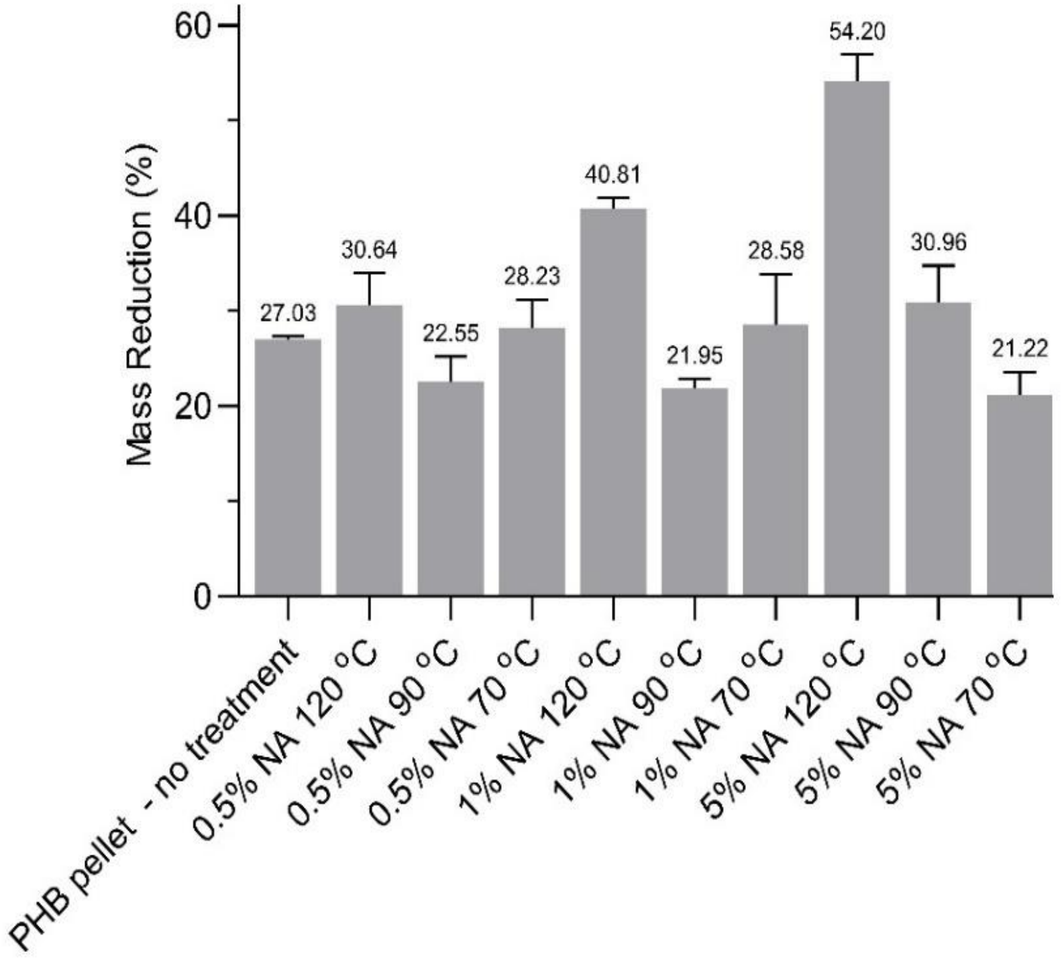


Pre-treatment of packaging waste by plasma-generated nitric acid

50 g/L PHB-pellets



Enzymatic hydrolysis with thermostable PHB-depoylymerases



Strategic research and innovation plan

Production

Segregated LCA of biobased processes leads to conflicting environmental impact assessment generating confusion to policy makers

- Develop safety/toxicity assessment models for **chemical and material production based on their life cycles**
- Include hydrolyzed bioplastics in the European Alliance of raw materials
- Develop toolboxes for comparative analysis of new approach methodologies

Disposal

Mismanagement elimination

- Develop **analytical tools to identify and quantify the composition** of complex waste streams
- Develop **sustainable processes** for improved life cycle management of additives
- Develop **multiple exposure models** allowing combined and aggregated exposure assessment, including modelling risks

Safety is linked to inherent properties, manufacture and use

LCA captures comprehensively impacts occurring upstream of the products' use

Development of new frameworks should cover all aspects of the value chain

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AGRICULTURAL UNIVERSITY OF ATHENS

THANK YOU

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BBI JU

Bio-based Industries Consortium

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EBC24 Side Event: Recycling strategies for bioplastics
December 2024

EBC24 European Bioplastics Conference

The industrial perspective of recycling. Exploring the Strategic Impact of the BIOMAC Project on Advancing Sustainability and Efficiency in the Recycling Industry

Ronny Salcedo Santana

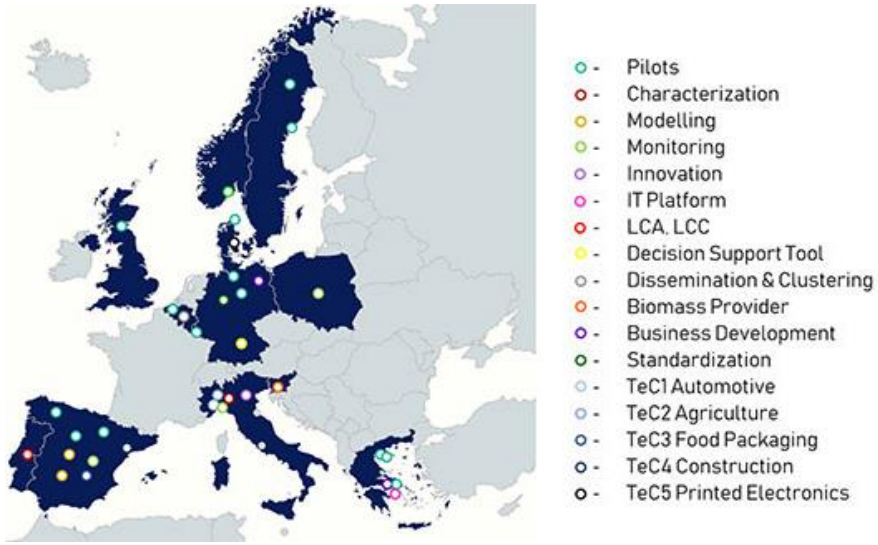
R&D Project Manager

European Sustainable BIO-based nanoMAterials Community

The project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941.

BIOMAC in a nutshell

- 34 participants.
- Budget of 17 million €
- BIOMAC Ecosystem is built by highly skilled experts in the field.
- BIOMAC Ecosystem will provide open access to its facilities (17 Pilot Lines) and services required for the development, testing and upscaling of materials and products in the field of nano-enabled bio-based products and materials.
- The Pilots Lines of BIOMAC cover the whole value chain, from biomass fractionation and intermediate chemicals to final Biobased Nanocomposites.



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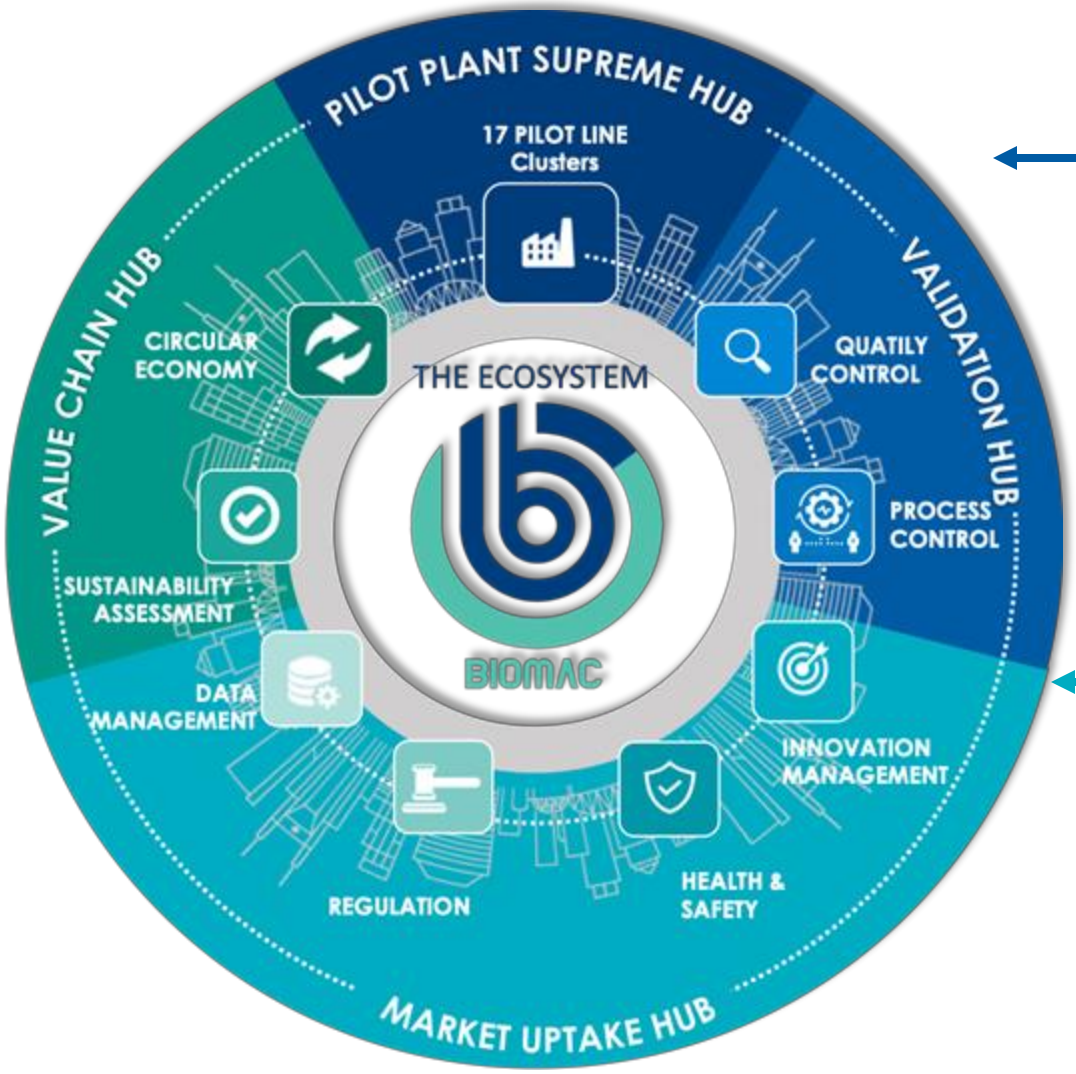
BIOMAC

Structure of the BIOMAC OITB: 4 Hubs

a) Biomass Fractionation and Pre-treatment Cluster
b) Intermediate Materials and Nanocomposite Cluster
c) Final Products and Formulation Cluster

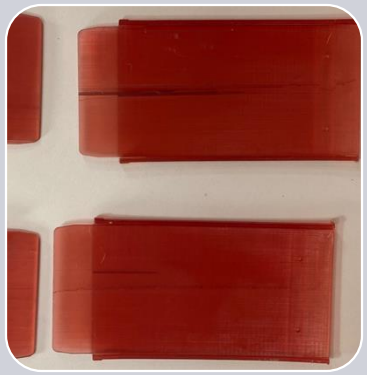
a) Sustainability assessment
b) Supply management
c) Circular economy



a) Quality control, characterisation
b) Process validation: modelling

a) Innovation management
b) Health and safety
c) Regulation & standardisation
d) Data management

The BIOMAC test cases

Automotive	Agriculture	Food packaging	Construction	Printed electronics
				
Tough, flexible, abrasion-resistant biomass-based UV-curable polyester urethane (LA, SA-derived) / NFC nanocomposites suitable for additive manufacturing	Recyclable and biodegradable bioplastics based on biopolymer (LA, SA-derived) nanocomposites with NFC, NL (1-3%) and biochar	Transparent compostable / biodegradable PLA film reinforced with BNC, NL and self-cleaning antibacterial surface with nanoimprint lithography	Biomass-based UV and fire-resistant, anti-fouling / easy-to-clean footbridge module defined for production via multi-material AM	Bio-based (conductive) inks reinforced by functionalized CNC BNC, and conductive biochar particles Flexible thermoplastic polyurethane (TPU) substrates produced via reactive extrusion

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PRECURE

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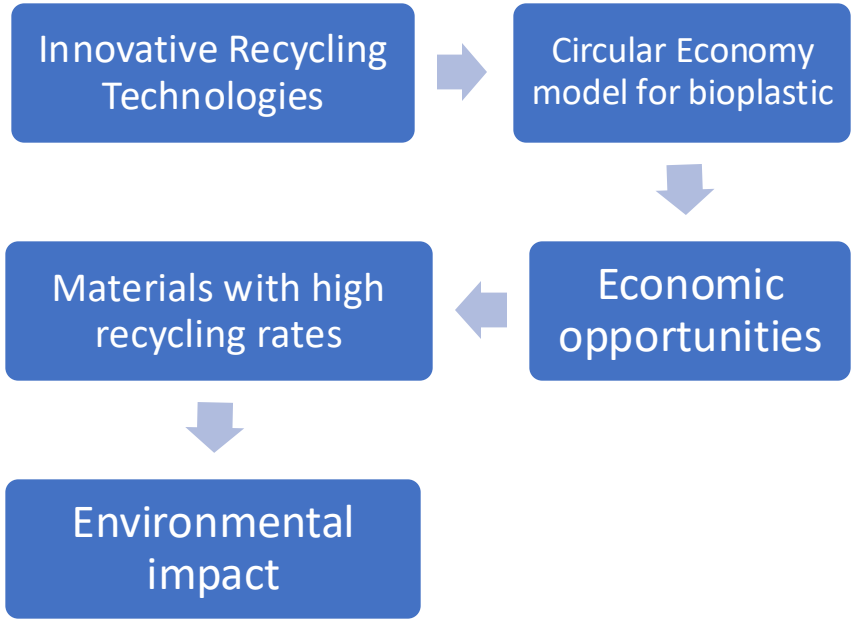
Potential benefits of BIOMAC project to face the challenges of the recycling Industry

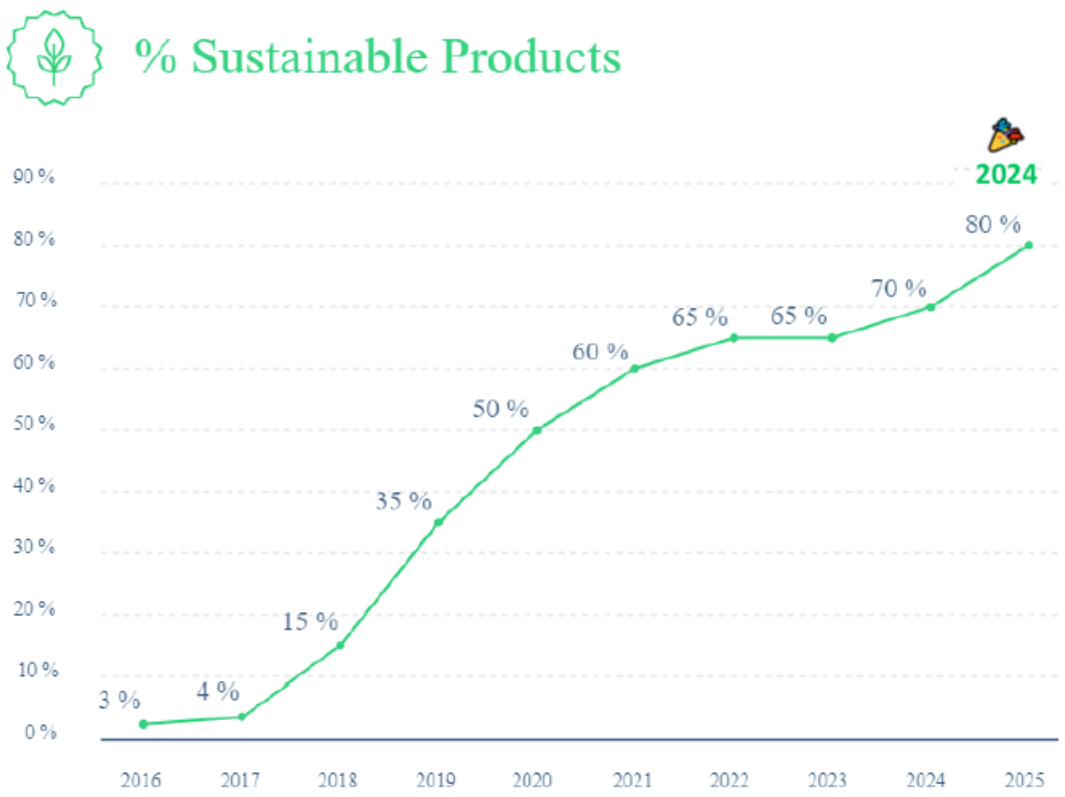
Challenges

- Limited Recycling infrastructure
- Sorting and identification
- Compostability
- Food Contact
- Economic Viability

Benefits



The commitment with sustainability



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Rc
RECYCLED

Ar
HIGH RECYCLABILITY

Bc
BIOCOMPOSTABLE

Pa
PAPER

BIOMAC

Some suggestions for improvement

Advance in sorting technologies

Chemical recycling innovation

Biodegradable plastic design

Product design (for recyclability)

Extended producer responsability (EPR) Scheme

Investment in R&D

Consumer Education Awareness

Subsides and Incentives

Thank you!

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www.biomac-project.eu