UPcycle

SUstainable PlastiC biorefinerY for reCyclable and biodegradabLE packaging

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Touch base with novel R&I projects working on bioplastics

Funded by the European Union under grant agreement number 101178389. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

MY BACKGROUND AND AREAS OF INTEREST

1) Fermentation and Bioprocess Technologies

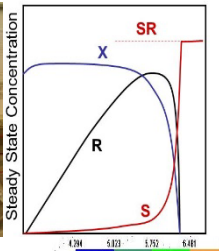
2) Biorefineries

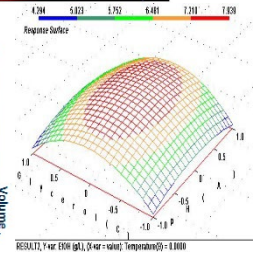
3) Eco-engineering of Mixed Microbial Cultures

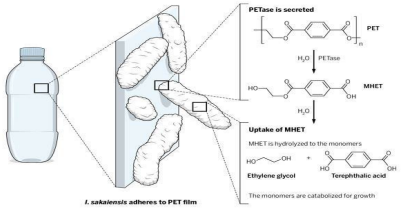
4) Optimization of process parameters

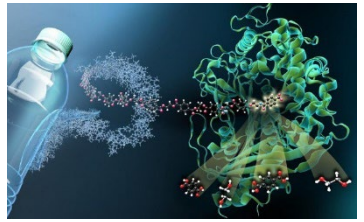
5) Biodegradation of recalcitrant pollutants

6) Bioupcycling of plastics









MY INTEREST IN THE PLASTIC FIELD

Plastic Biorefening and Bioupcycling team *(group leader)*:

https://www.bio.aau.dk/forskning/sektioner/bioresources-and-process-engineering/plastic-biorefining-and-bioupcycling

- Enzymatic depolymerization of polyesters
- Enrichment and adaptation of microbial consortia on plastic waste
- Microbial upcycling of plastic monomers
- Polyolefin pyrolysis wax bioupcycling into PHAs
- Valorization of industrial waste streams into bioplastics (Novonesis PhD)

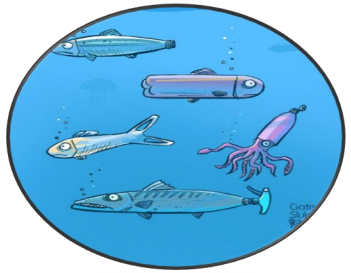
AAU Circular Plastic Platform *(Vice-chair)*:

https://www.en.aau.dk/research/interdisciplinary-research/circular-plastic

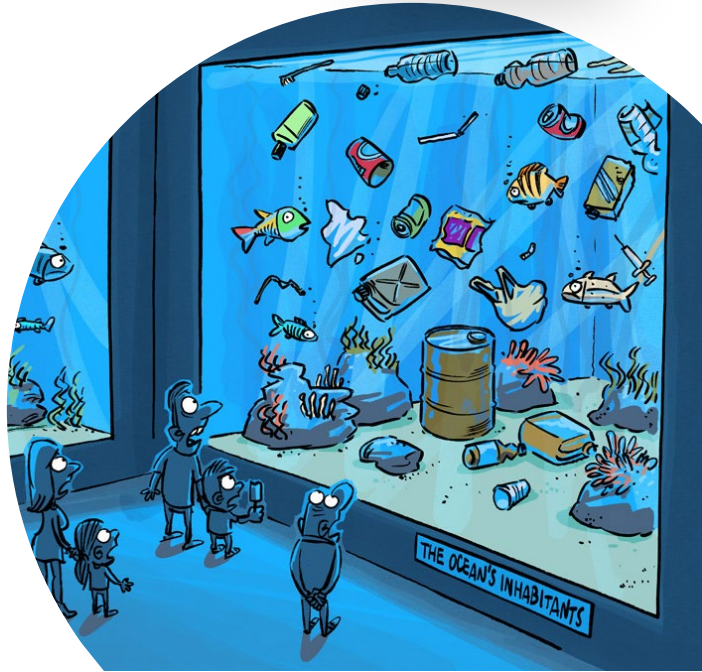
- AAU Circular Plastics is a collaborative platform where researchers across faculties and departments can connect, collaborate, and collectively work towards transforming the way plastics are used, recycled, and managed.
- Beyond academia, we strive to actively **engage with industry and policymakers to promote the adoption of sustainable practices** and support decision-making for the transition to a circular plastics economy.

OUTLINE

- Introduction: UPCYCLE and the Plastic Biorefinery
- Building on H2020 UPLIFT's key findings
- Challenges to overcome
- The UPCYCLE project
- Conversion routes and end-user applications



Something is fishy here…

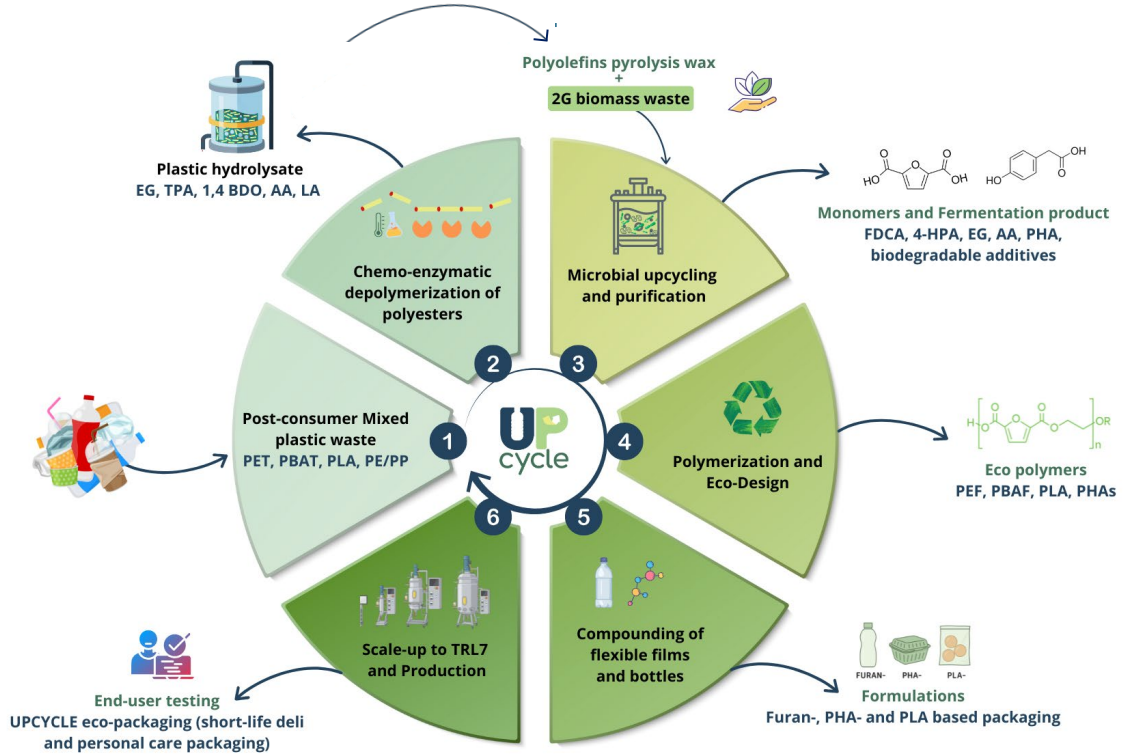


SUstainable PlastiC biorefineriY for reCyclable and biodegradabLE packaging

Turning non-recyclable mixed plastic waste into next-generation compostable and recyclable packaging

SAFE-AND-SUSTAINABLE-BY-DESIGN

UPCYCLE'S PLASTIC BIOREFINERY



UPCYCLE'S END USER APPLICATIONS

Food packaging

Cosmetics

@upcycle-plastics

www.upcycle-plastics.eu

@UPCYCLEplastics

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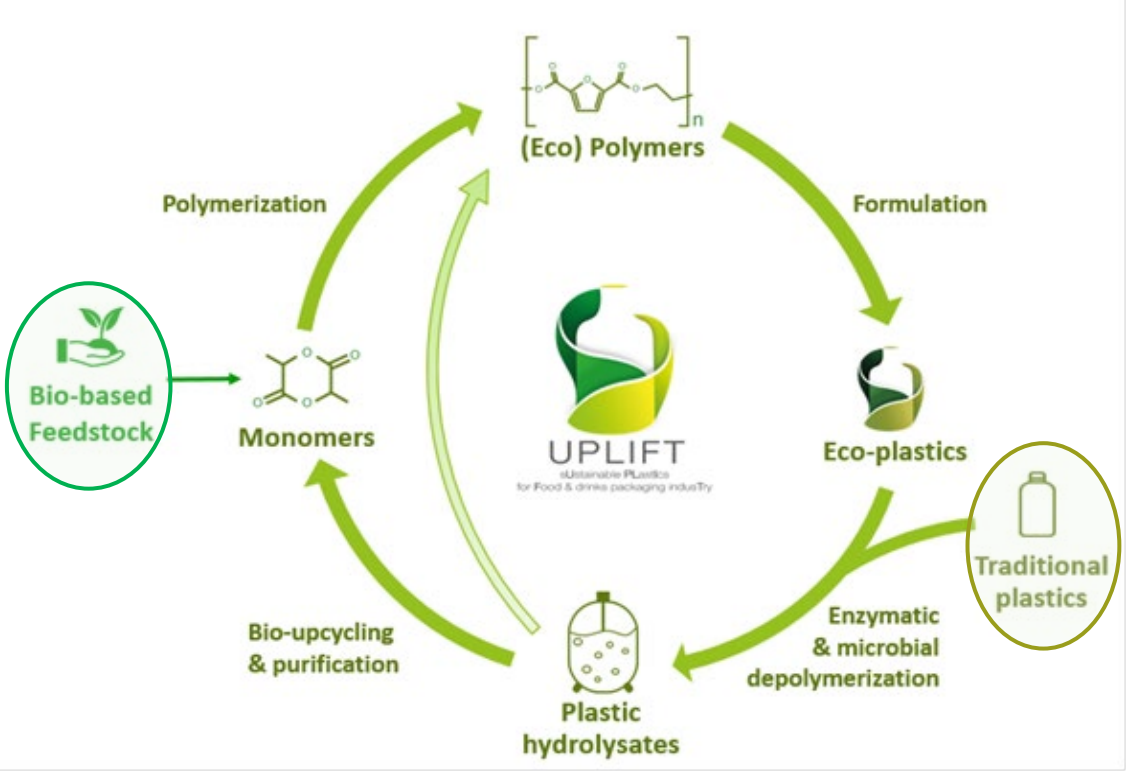
FROM UPLIFT TO UPCYCLE

Post-consumer plastic waste as a feedstock for unconventional Biorefineries

UPCYCLE builds on the promising results of the H2020 UPLIFT project (TRL 3-5), addressing key scalability challenges to achieve economic viability.

It will also link UPLIFT's results and publications to ensure that industry and researchers can easily trace how these outcomes evolve and feed into UPCYCLE.



- https://upliftproject.eu/
- https://cordis.europa.eu/article/id/459633-the-biotech-solution-that-recycles-trickier-plastic-waste

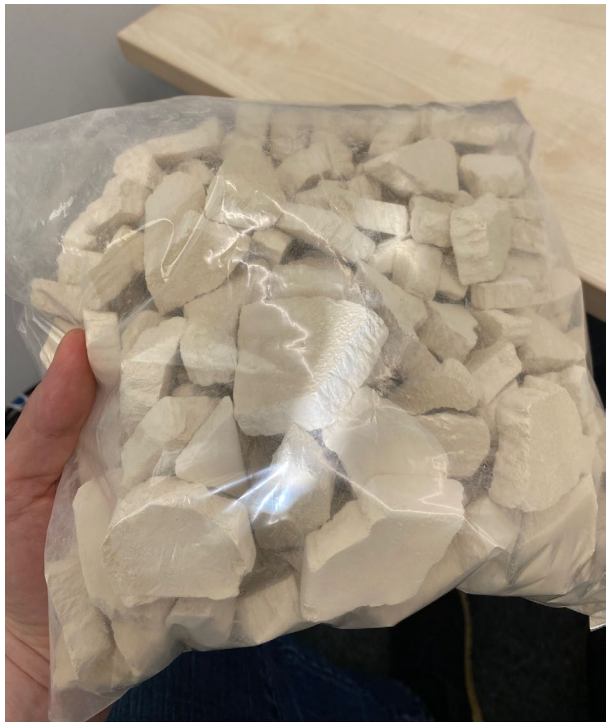
Depolymerization of post-consumer PET in 300 L reactor using ICCG supernatant

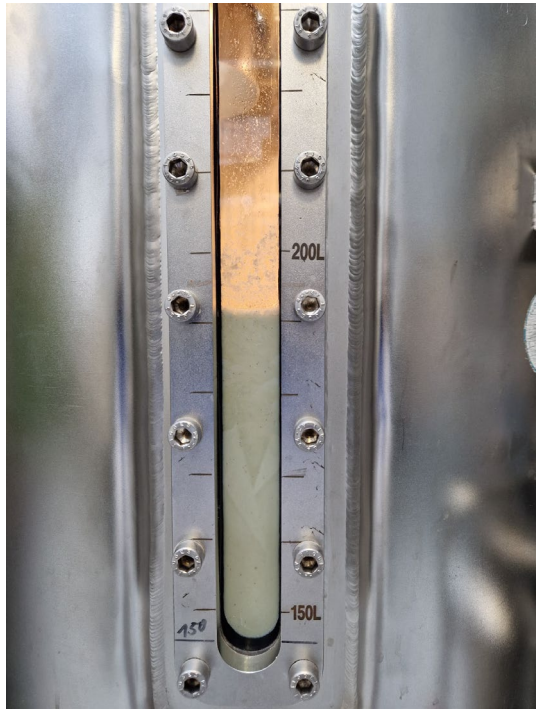
Seed train of *E.coli* BL21

30 L fermenter

300 L fermenter

150 g/L PC mixed PET waste
(bottles and trays 50:50)





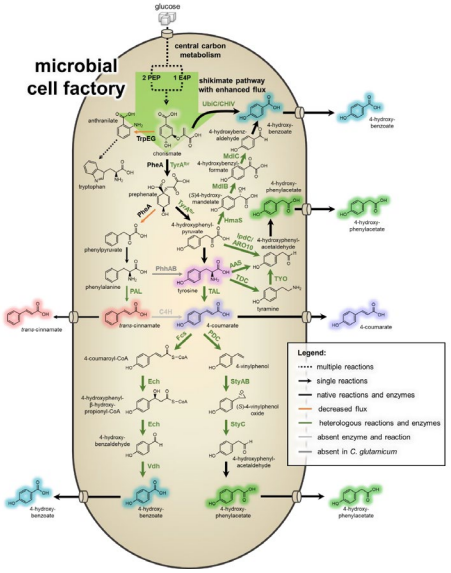
Feedstock loading: ~ 25 Kg of mixed PET waste
12 Kg of TPA sent to UCD for upcycling

rPET
PET-HPA

PHA
PEF

1500L fermentation of bio-based building blocks using engineered strains

4-hydroxy phenylacetate (4-HPA) is a bio-based compound that serves as a key building block for plastics



JÜLICH FORSCHUNGSZENTRUM

LEIBNIZ HKI

Bio Base Europe Pilot Plant

Strain development 0.1g/L

Tech Transfer 1g/L

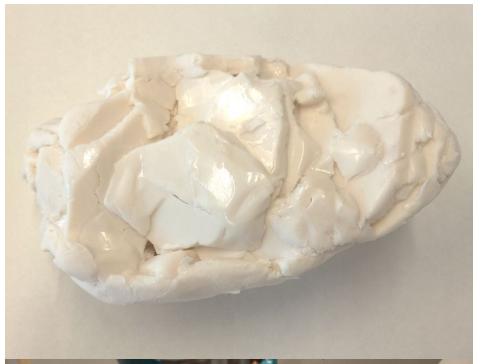
Scale-up 10g/L

Bio Base Europe Pilot Plant scaling up the production of 4-HPA with engineered strains from FZJ and Tech Transfer from HKI. https://upliftproject.eu/uplift-milestone-aromatics-packaging/

JÜLICH Forschungszentrum

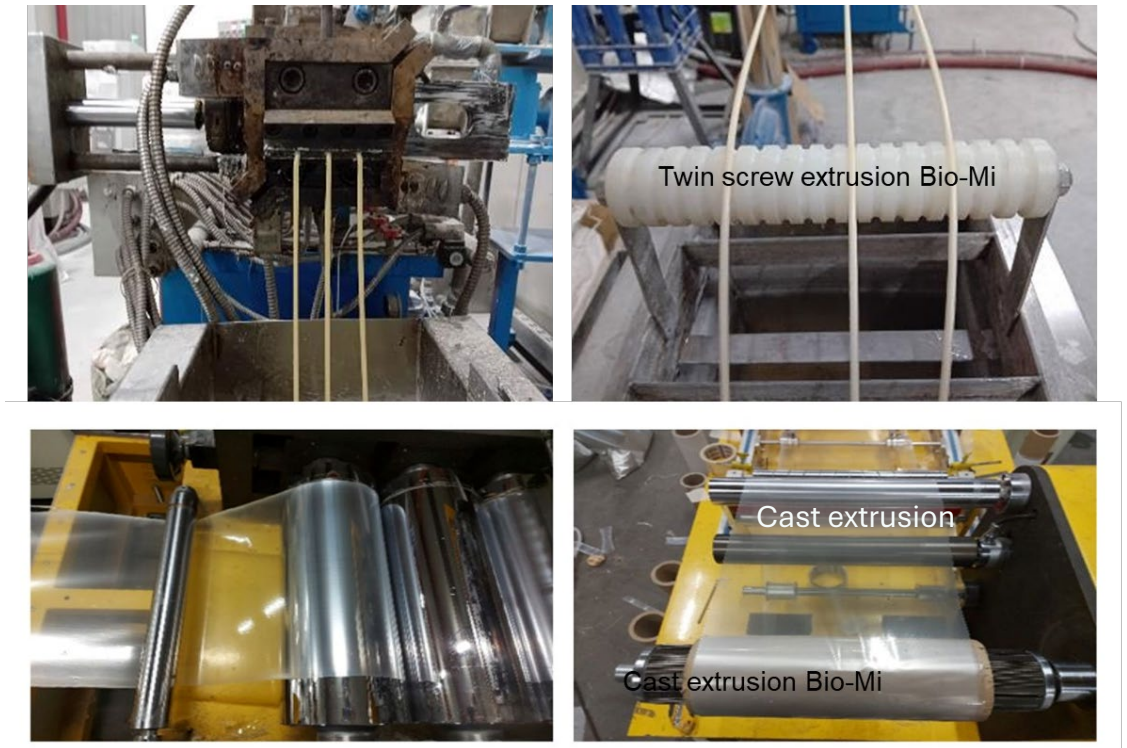
Eco-design and polymerization of novel “eco-polymers”

- 4-HPA homopolymer production **(pHPA)** for compounding assesment
- Scaling of poly(HPA) with lactide
- Scale up production of **bio-based additive** (P5) for compounding processes: up to 2kg.
- Synthesis of PLA by reactive extrusion:
  - Molecular weight: 140-150 kDa
  - Suitable for film extrusion or injection moulding



4-HPA homopolymer

Processability and recyclability of UPLIFT's flexible films



Formulation and compounding for flexible films by **Bio-Mi**

- PLA LX175/pHPA had the lowest OTR among the tested samples, providing the best oxygen barrier performance.
- PLA LX175/P5/PHO had the lowest WVTR, making it the most effective film at blocking moisture.
- PLA LX175/P5 showed an increase in WVTR, meaning it is more permeable to moisture than PLA LX175

Processability and recyclability of UPLIFT's bottles

AIMPLAS Injection Stretch Blow Molding (ISMB) tests with different UPLIFT formulations

Commercial PLA

UPLIFT PLA

Coloration problems (PHO)

- PLA + PHO demonstrated superior processability in both the injection and blow molding stages compared to the commercial PLA Luminy LX175
- PHO addition helped reducing resistance to polymeric flow within the mold cavity.
- Additionally, the reduction in blowing temperatures indicates a lower softening temperature, leading to potential energy savings in ISBM production.

Processability and recyclability of UPLIFT's rigid trays

TECNARO flat sheet extrusion for rigid packaging

Thermoforming process

- Thermoforming tests to determine the optimum shell thickness have shown that film cracks and holes occur from a thickness of less than < 100 µm
- The stability of the trays is guaranteed with a tray thickness of 250-150 µm
- The food trays show good mechanical stability, but barrier properties still need to be tested

UPLIFT's ecopolymer packaging

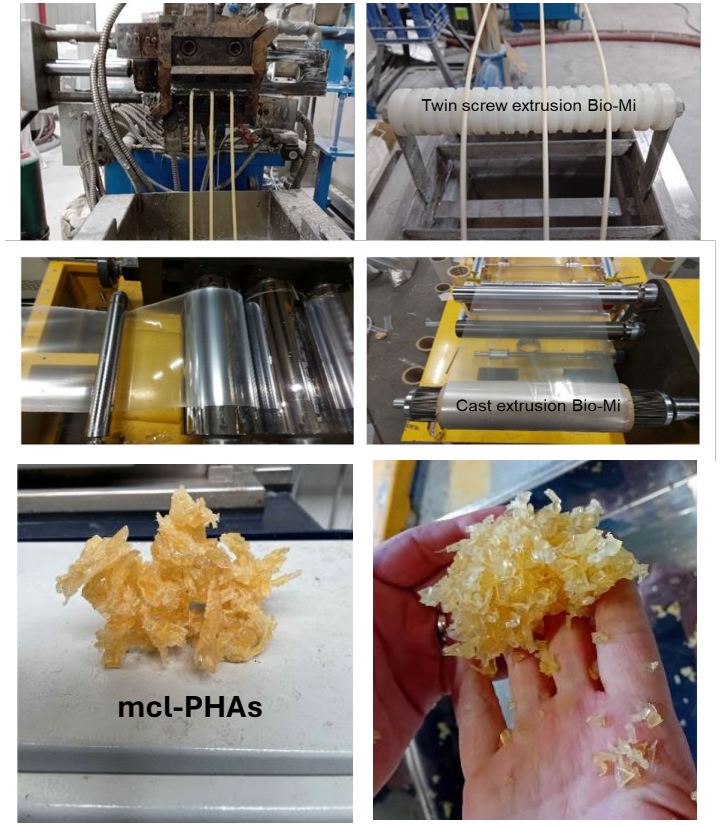
Compromise between processability and mechanical properties

Bio-Mi samples of films produced

Tecnaro thermoforming tests to determine the optimum shell thickness

Lessons learned and Future perspectives

- Lower activity on real plastic waste with high crystallinity
- Low titers of new pathways from waste streams
- DSP at 1500L scale might require additional steps to keep same efficiency (and still large material loss!)
- The best choice for the bioprocess is not necessarily the best for the end user (information loop!)
- Economic viability is still a major bottleneck

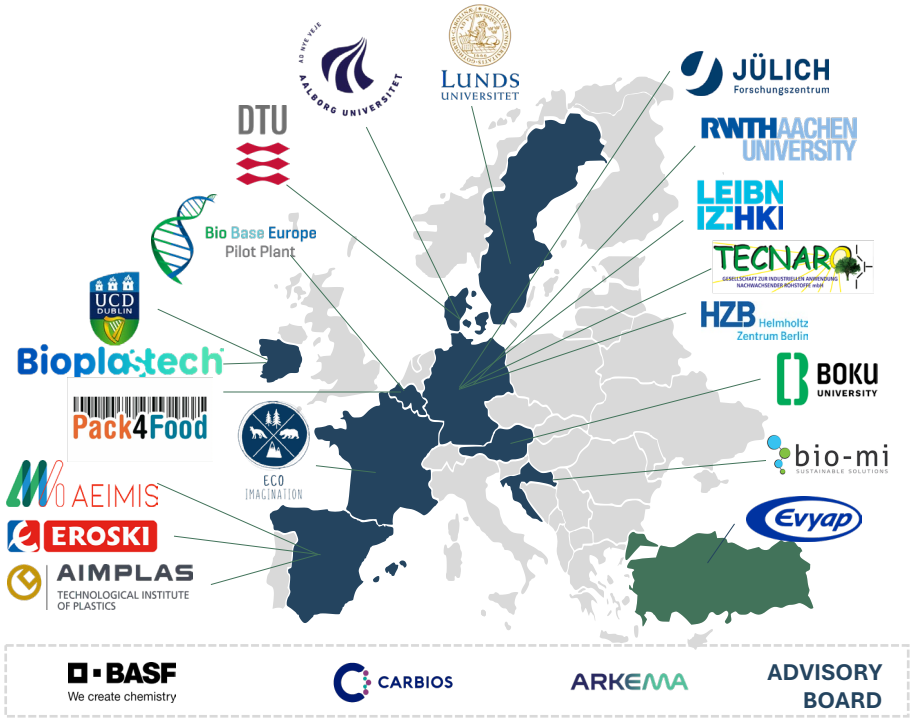


Processability of UPLIFT's ecopolymers

What's next: sUstainable PlastiC biorefinerY for reCyclable and biodegradabLE packaging

Horizon Europe Innovation Action (TRL7): September 2025-August 2029

Nº	ORGANISATION NAME	SHORT NAME	COUNTRY	TYPE*
1	AALBORG UNIVERSITET	AAU	DK	UNI
2	EROSKI SCOOP	EROSKI	ES	LI
3	EVYAP SABUN YAG GLISERIN SANAYI VETICARET ANONIM SIRKETI	EVYAP	TR	LI
4	PACK4FOOD	Pack4food	BE	ASO
5	BIO-MI DRUSTVO S OGRANICENOM ODGOVORNOSCU ZA PROIZVODNJU, ISTRAZIVANJE I RAZVOJ	BIO-MI	HR	SME
6	TECNARO GMBH	TECNARO	DE	SME
7	BIO BASE EUROPE PILOT PLANT VZW	BBEPP	BE	SME
8	BIOPLASTECH LTD	BPL	IE	SME
9	DANMARKS TEKNISKE UNIVERSITET	DTU	DK	UNI
10	ASOCIACIÓN DE INVESTIGACIÓN DE MATERIALES PLÁSTICOS Y CONEXAS	AIMPLAS	ES	RTO
11	LEIBNIZ-INSTITUT FUR NATURSTOFF-FORSCHUNG UND INFEKTIONSBIOLOGIE EV HANS-KNOLL-INSTITUT	L-HKI	DE	RTO
12	FORSCHUNGSZENTRUM JULICH GMBH	FZJ	DE	RTO
13	UNIVERSITAET FUER BODENKULTUR WIEN	BOKU	AT	UNI
14	HELMHOLTZ-ZENTRUM BERLIN FÜR MATERIALIEN UND ENERGIE GMBH	HZB	DE	RTO
15	LUNDS UNIVERSITET	ULUND	SE	UNI
16	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	RWTH	DE	UNI
17	UNIVERSITY COLLEGE DUBLIN	UCD	IE	UNI
18	ASOCIACION ESPAÑOLA DE LA INNOVACIÓN EN EL MARKETING Y LA INVERSIÓN SOSTENIBLE	AEIMIS	ES	NGO
19	ASSOCIATION ECO IMAGINATION	ECO	FR	NGO



19 Partners from 10 different Countries

The Horizon call requirements

HORIZON-cl4-2024-resilience-01-35: Biodegradable polymers for sustainable packaging materials

Type of call: 2-stage Innovation Action
Deadline dates: 07 February 2024 and 24 September 2024
TRL: 4 to 6-7
Budget: 6-8 mio €

Destination: Increased Autonomy in Key Strategic Value Chains for Resilient Industry

- **Industrial leadership** through reduced strategic dependencies on third countries and autonomy in key strategic value chains
- Enhancing **EU's resilience** and flexibility both in terms of technologies and supply chains
- Access to critical raw materials, technologies and services that are safe and secure for industry as a whole *(**diversify internal supply chains**)*
- **Effective reuse and recycling** and clean primary production of raw materials

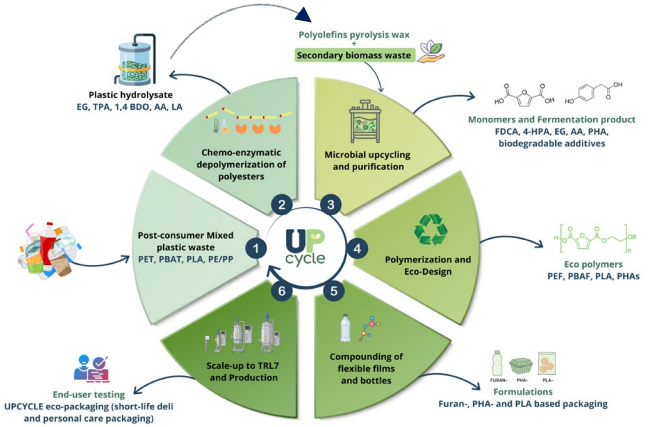
Scope: Proposals should address at least four of the following activities:

- Develop and **scale-up novel advanced bio-degradable polymer** materials **and innovative processes** that will allow large-scale production
- Similar **economy of scale** to replace production **of PE, PP and PET**, but with an **improved sustainability**
- Develop **sustainable additives and catalysts** to support the production of bio-degradable polymers.
- Scale up the **production of packaging** materials at **pilot level**.
- Test **biodegradability pathways** in all environmental conditions

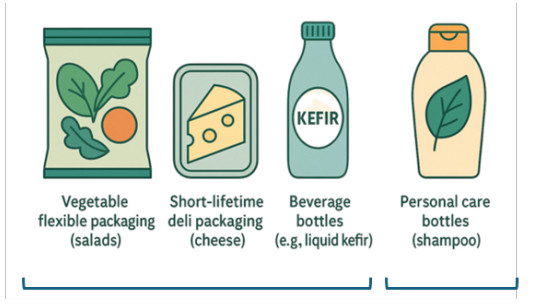
Main objectives of UPCYCLE

- ✓ Demonstration of a **versatile biorefinery process** to valorise mixed plastic waste (both fossil- and bio-based) and biomass residues;
- ✓ **AI-powered** fast-track innovation for **process intensification;**
- ✓ **Smart polymerisation and formulation** strategy using bio-based, degradable additives to tune recyclability/biodegradability and enhance and **fine-tune the technical performance for 4 selected packaging use-cases**;
- ✓ **Safe-and-Sustainable-by-Design** framework to ensure safety (i.e. non-toxic materials), a reduction in GHG emissions (-30%);
- ✓ **Improved economic viability** of the new ecopolymers (<40% selling price).

UPCYCLE'S PLASTIC BIOREFINERY

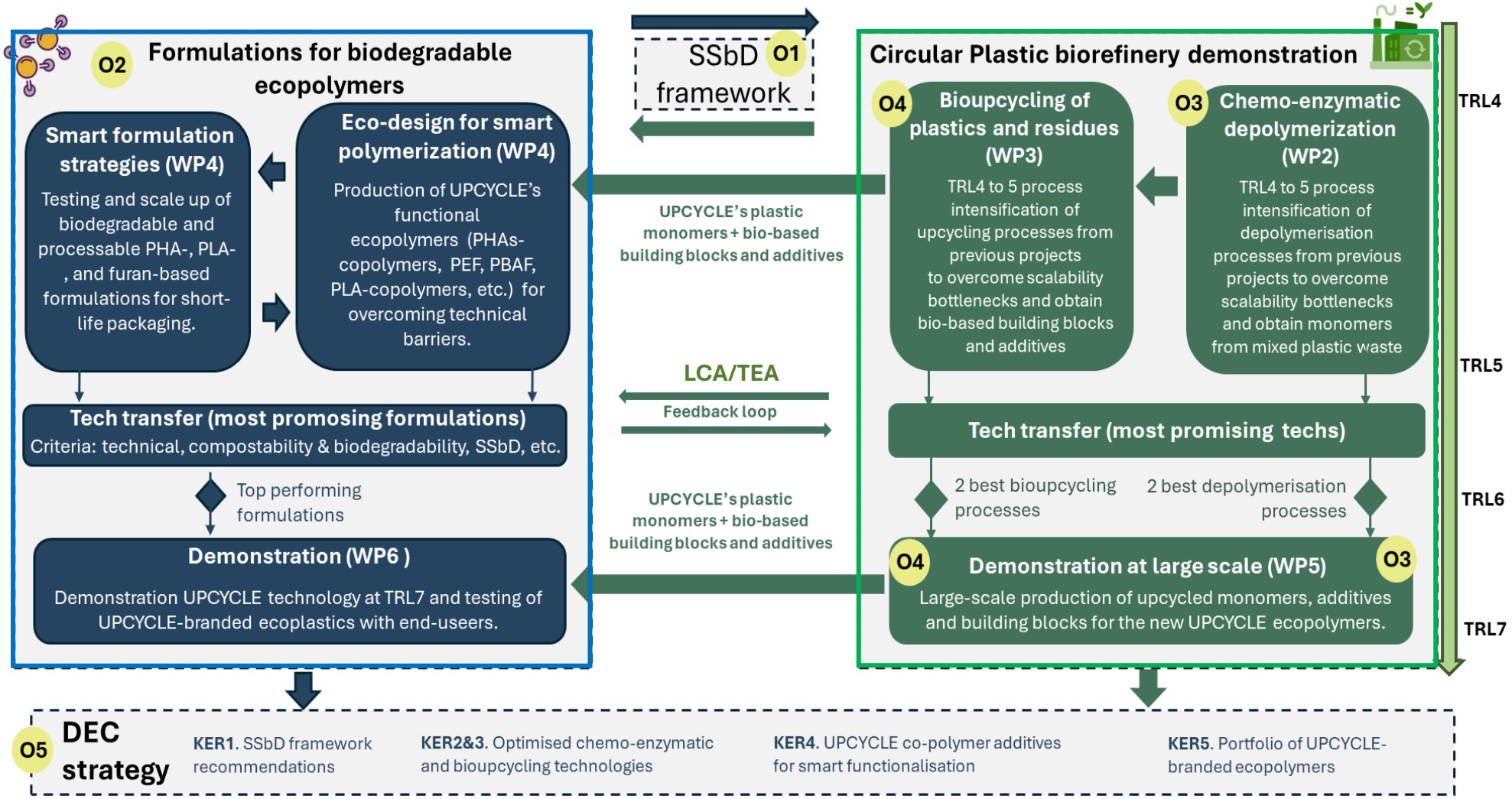


UPCYCLE'S END USER APPLICATIONS

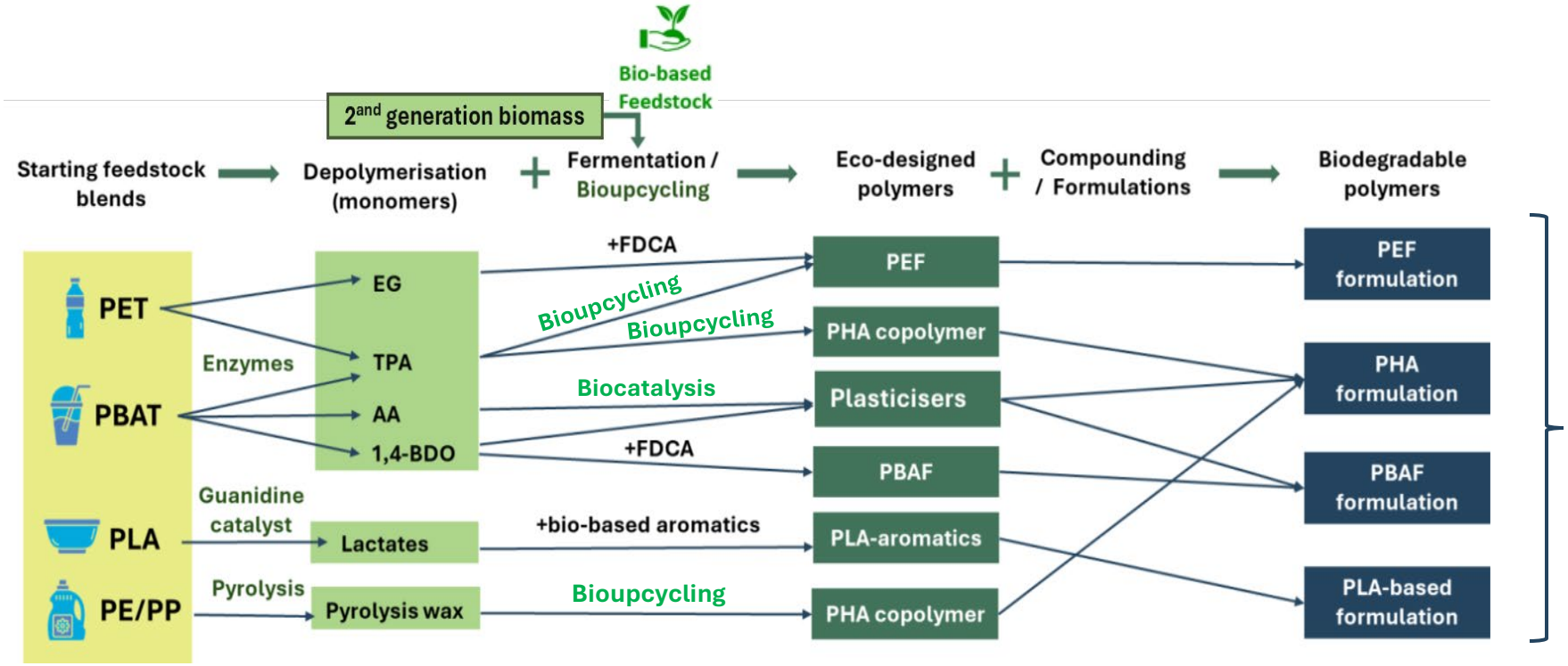


PHA-, PLA and Furan-based packaging formulations

UPCYCLE's approach and Outcomes



UPCYCLE conversion routes



Short-lifetime deli packaging (EROSKI)

Vegetable flexible packaging (EROSKI)

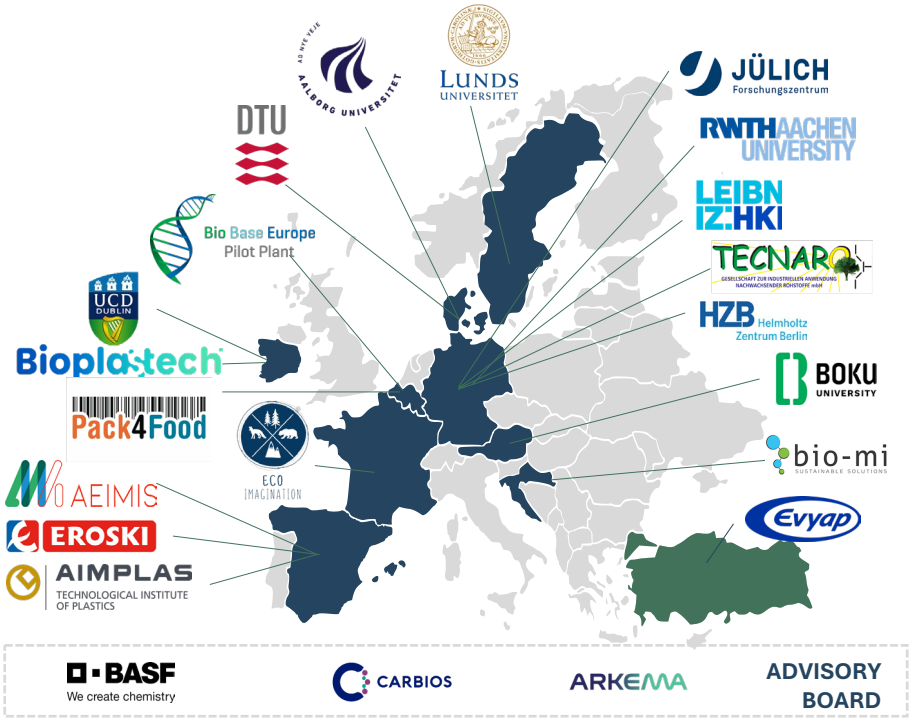
Beverage bottles (EROSKI)

Personal care packaging (EVYAP)

UPCYCLE'S END-USER APPLICATIONS

Collaboration opportunities

- ✓ JOIN UPCYCLE'S INDUSTRIAL ADVISORY BOARD
- ✓ END-USER APPLICATIONS
- ✓ SCIENTIFIC COLLABORATIONS
- ✓ CLUSTERING AND NETWORKING
- ✓ SCIENCE-TO-POLICY



To be continued..

Greetings from the UPCYCLE consortium

UPCYCLE Kick-off meeting at BBEPP (Ghent, 8-9 October 2025)

UP cycle

THANK YOU

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www.upcycle-plastics.eu

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