ERA CoBioTech

Imperial College London

Microbial Integration of Plastics in the Circular Economy (MIPLACE)

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Imperial College London

MIPLACE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant 722361

27.09.2021

Project partners

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RWTH Aachen University
Germany

Prof. Zimmermann
Dpt. Microbial and Bioprocess Technology
University of Leipzig
Germany

Dr Porcar
I2SysBio
University of Valencia
Spain

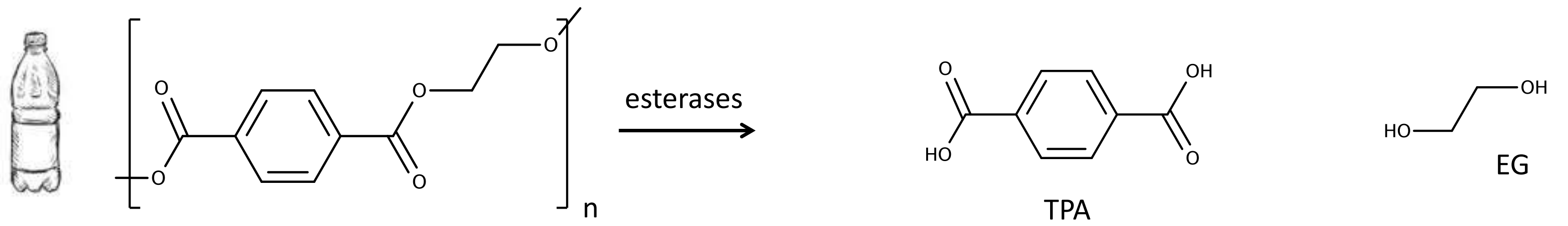
Eng. Perrin
Soprema group
France

- Total project budget: EUR 1.694 m
- Duration 3 years

Introduction

- PET is among the polymers with the highest recovery rates (70% in Europe)
- Only 7% of it is turned into new containers (World Economic Forum, 2015)

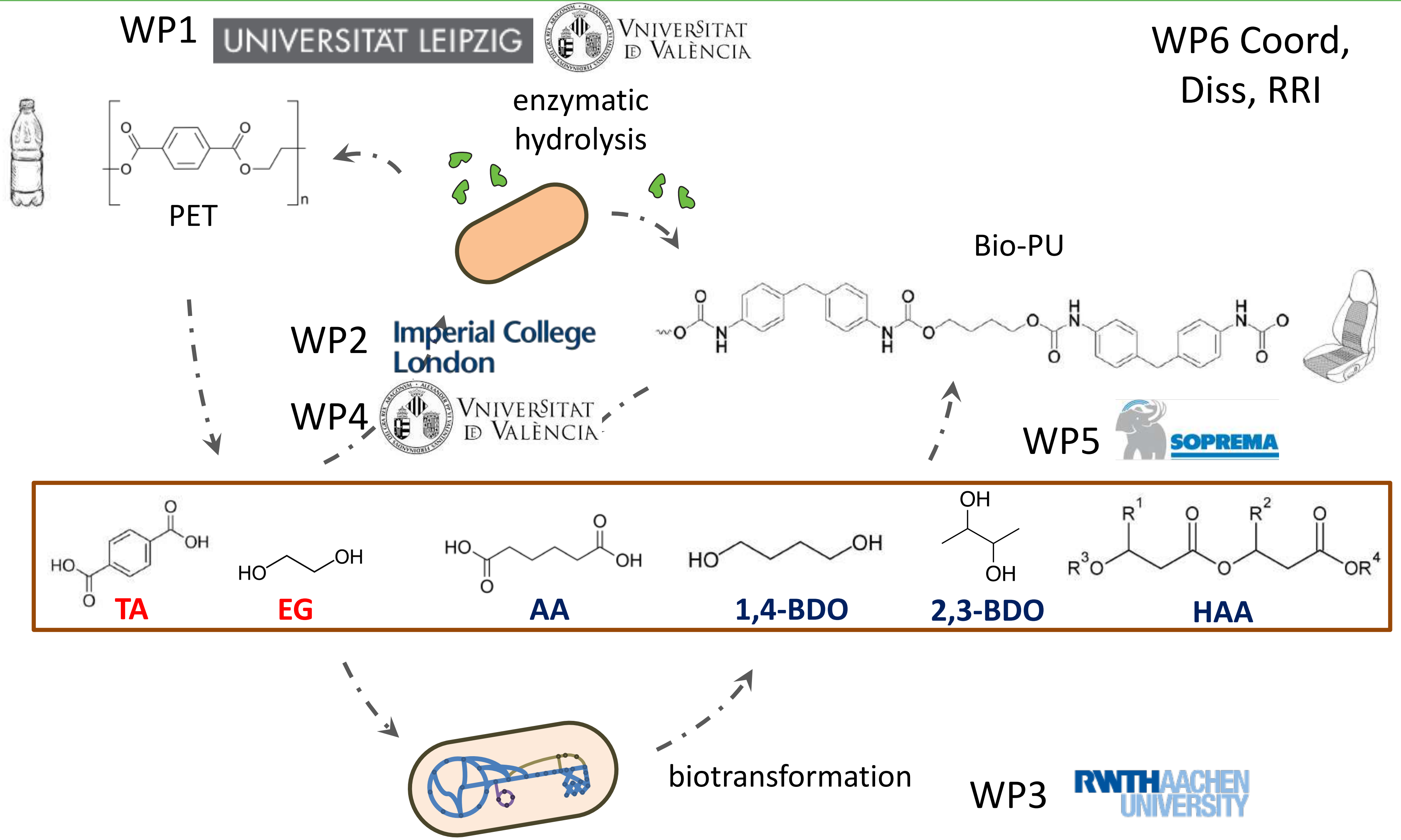
Introduction



- Objective: **Turn post-consumer PET into a microbial feedstock** for its up-cycling into polymers with added value

- Approach: Engineer microbial communities that can **reliably** assimilate PET and produce building blocks for bio-PU

Project plan



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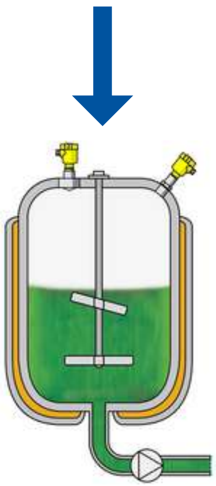
WP1: Hydrolysis of PET

MIPLACE

- **Enzymatic hydrolysis of post-consumer PET**

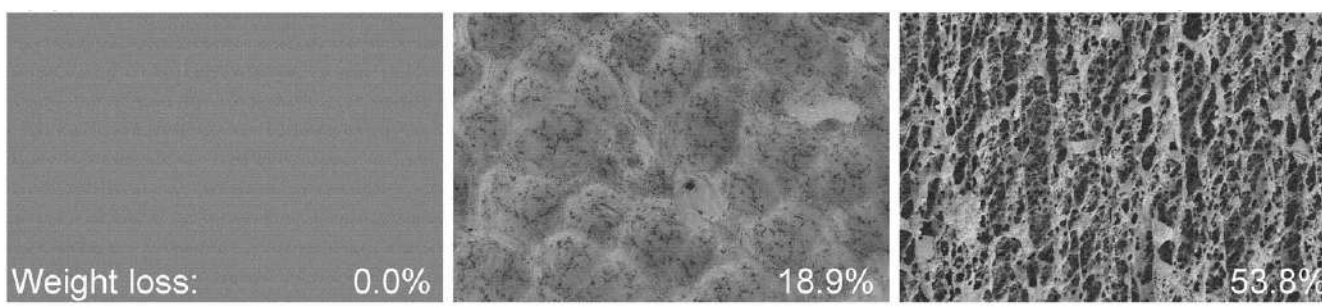


- PET food packages dissolved at 60-70 deg

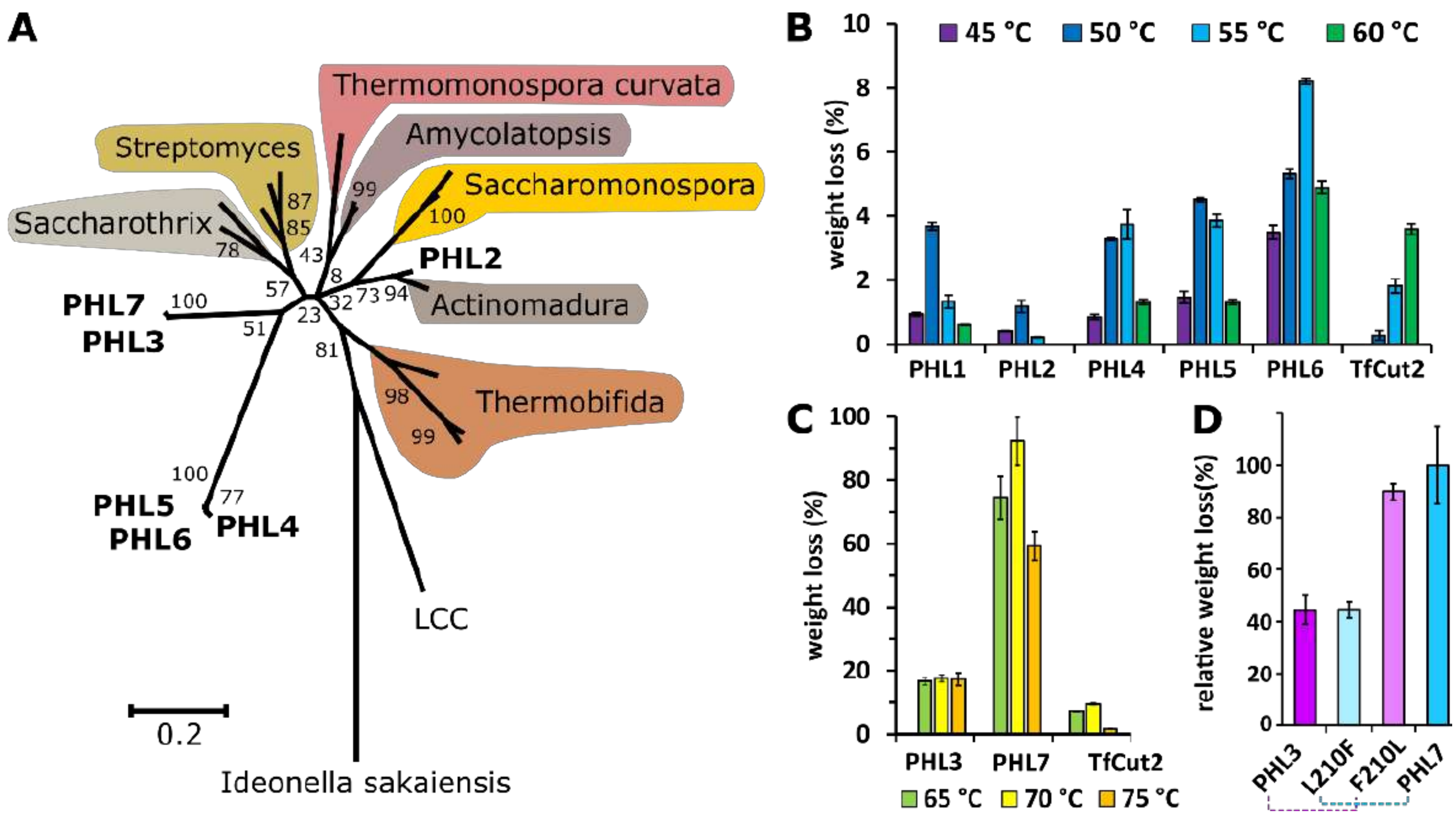
Dr C. Sonnendecker

Prof. W. Zimmermann

UNIVERSITÄT LEIPZIG



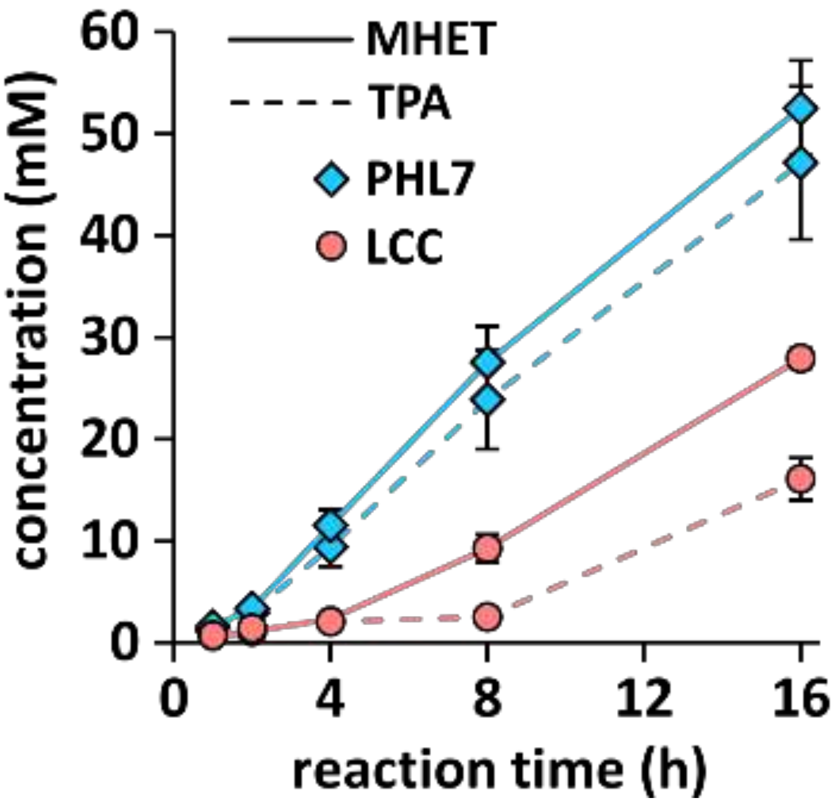
- **Enzymatic hydrolysis of post-consumer PET**

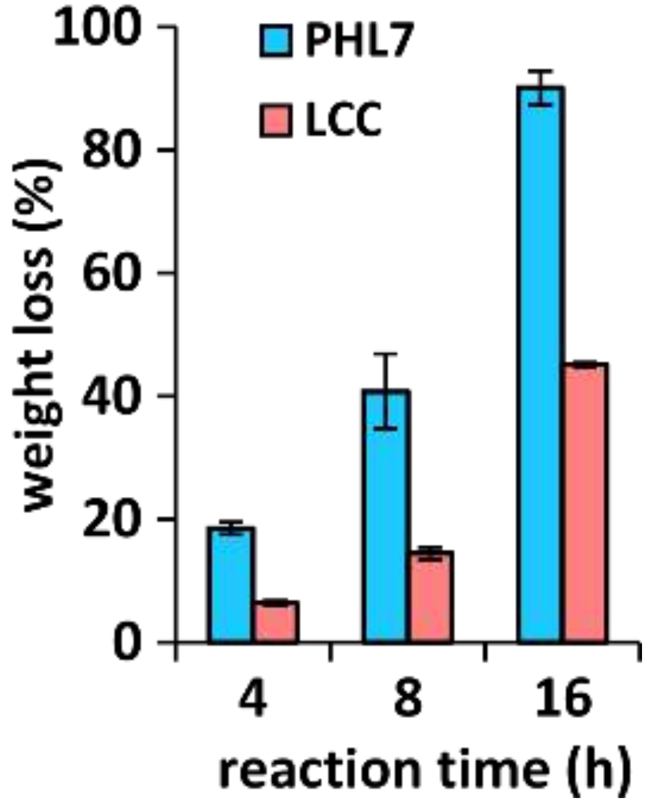


Sonnendecker *et al.* (2021), Low Carbon Footprint Recycling of Post-Consumer PET Plastic with a Metagenomic Polyester Hydrolase. ChemSusChem. In press.

WP1: Hydrolysis of PET

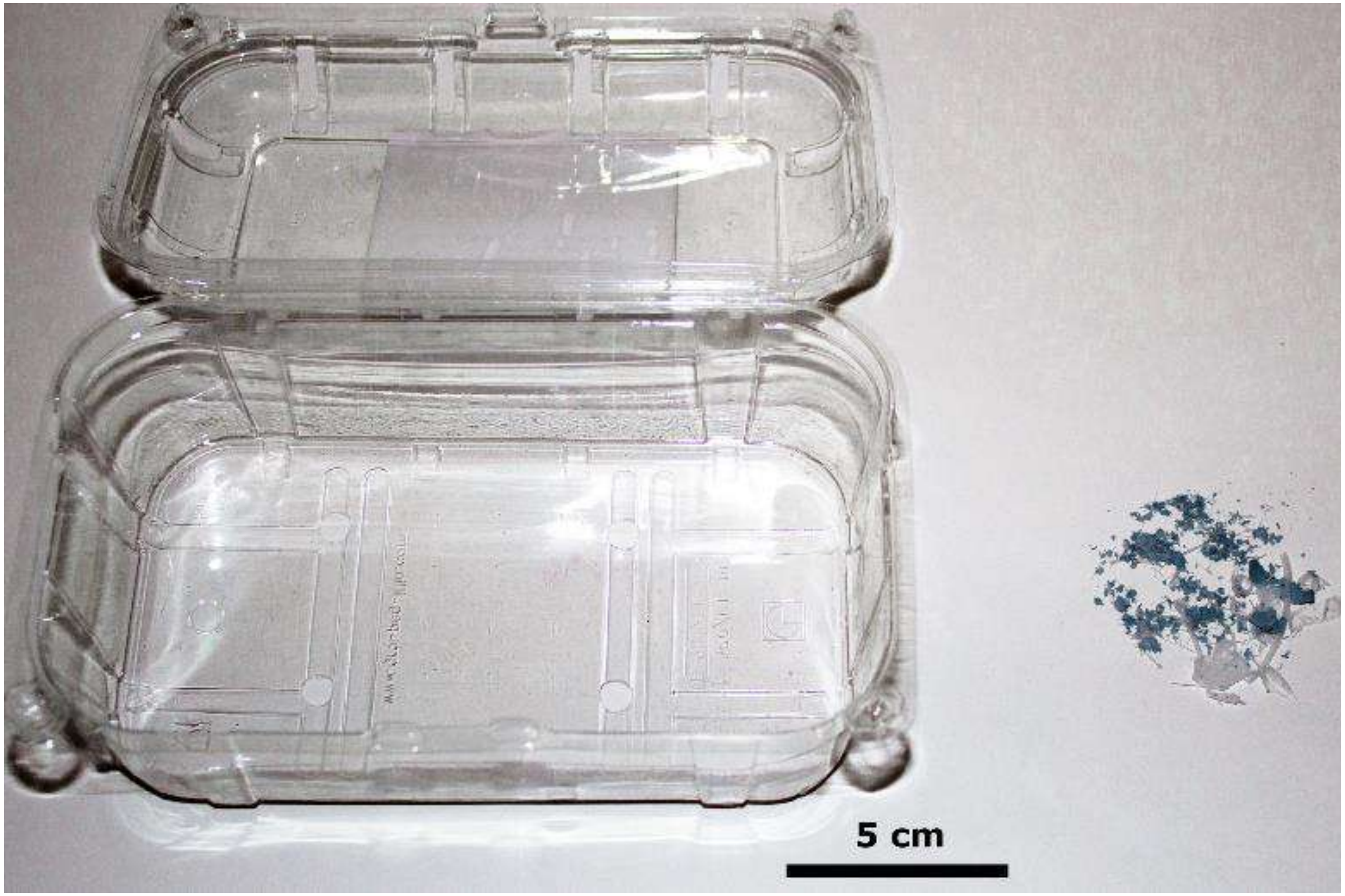
- **PHL7 has higher activity than LCC against PET films**





WP1: Hydrolysis of PET

- **Post-consumer PET degradation by PHL7**



WP1&4: Hydrolysis of PU and system analysis of communities

- **Microbial activities against PU**

Sampling

24 samples from 15 locations

Dr A. Iglesias

Dr M. Porcar

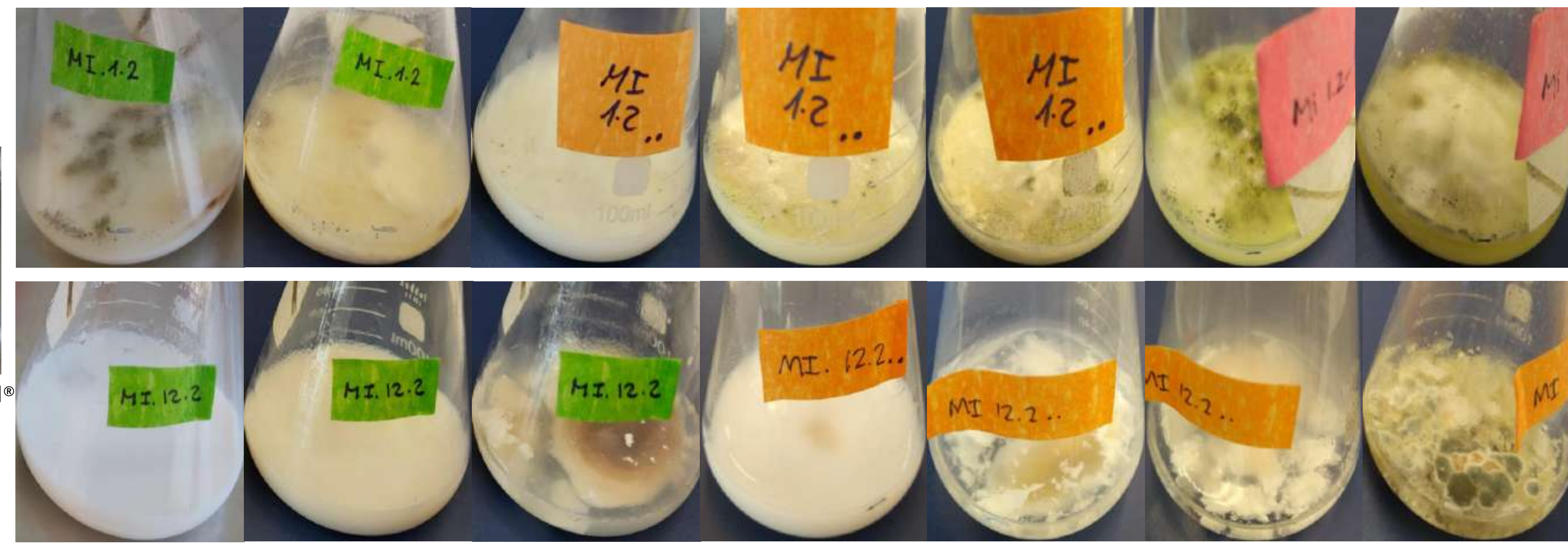
Universitat de València

WP1: Hydrolysis of PU

Screening of microorganisms active against PU

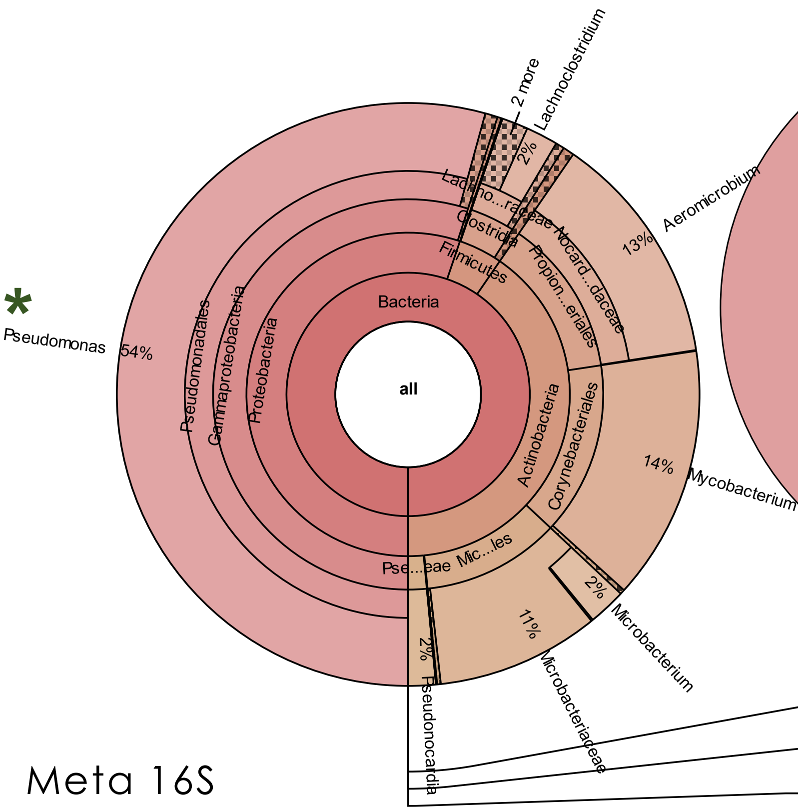
Inoculation → Growth check point 1 → GCP2 → GCP3 → GCP4 → GCP5 → GCP6 → GCP7

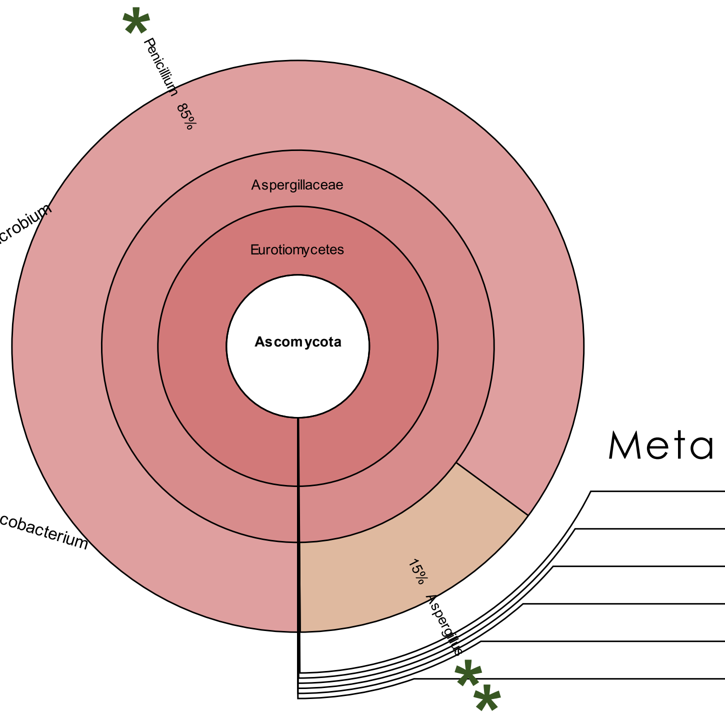
M9+Impranil®



WP1: Hydrolysis of PU

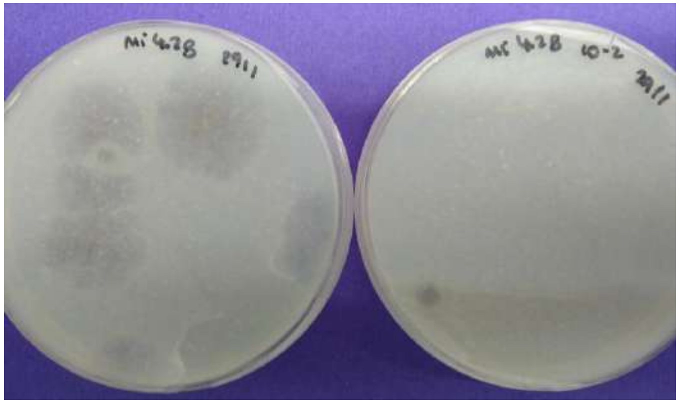
- **Screening of microorganisms (community analysis 16S/ITS)**

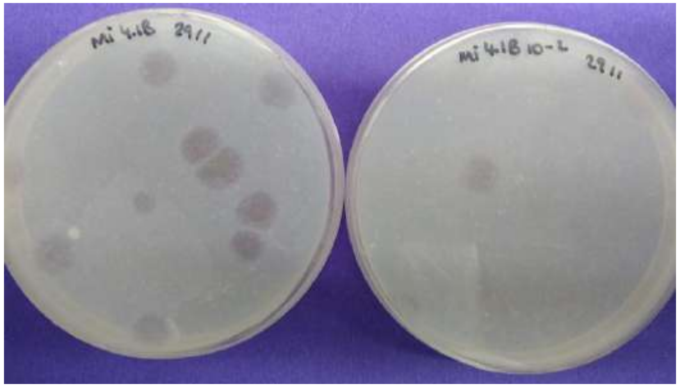


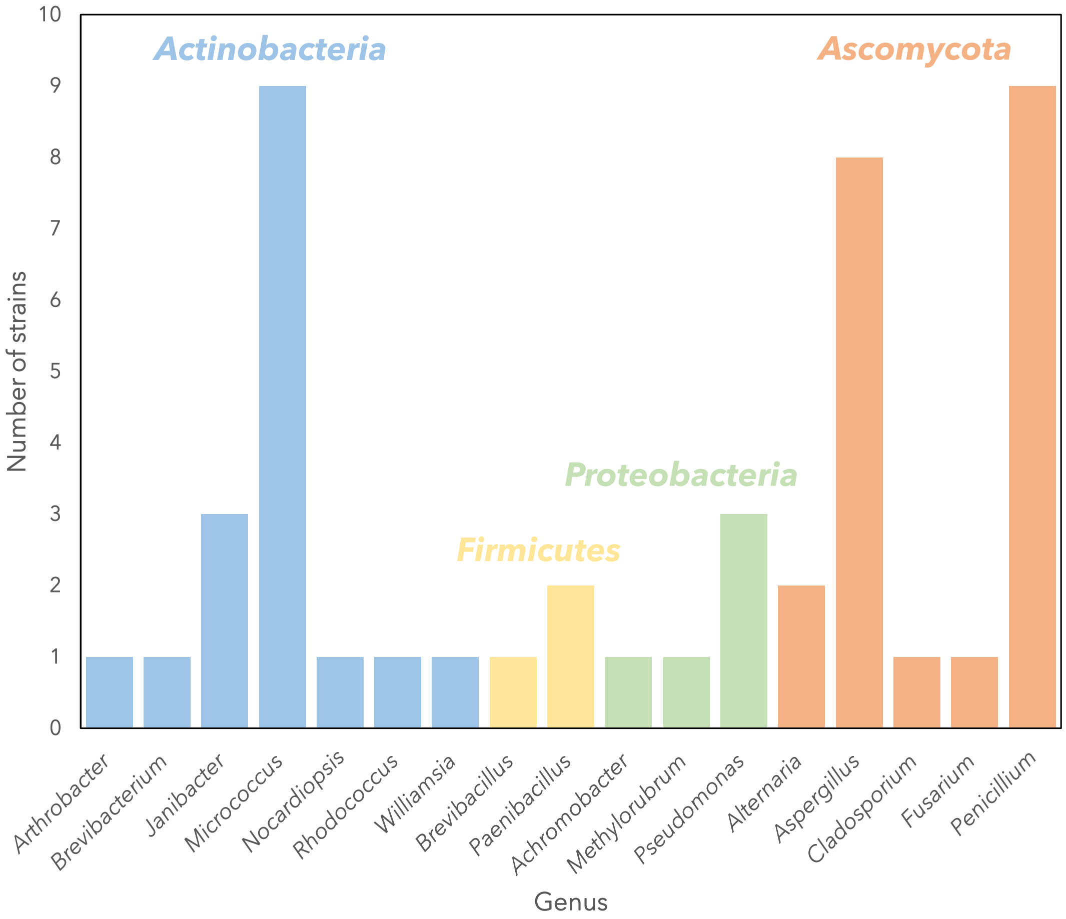


WP1: Hydrolysis of PU

Strain isolation and whole genome sequencing







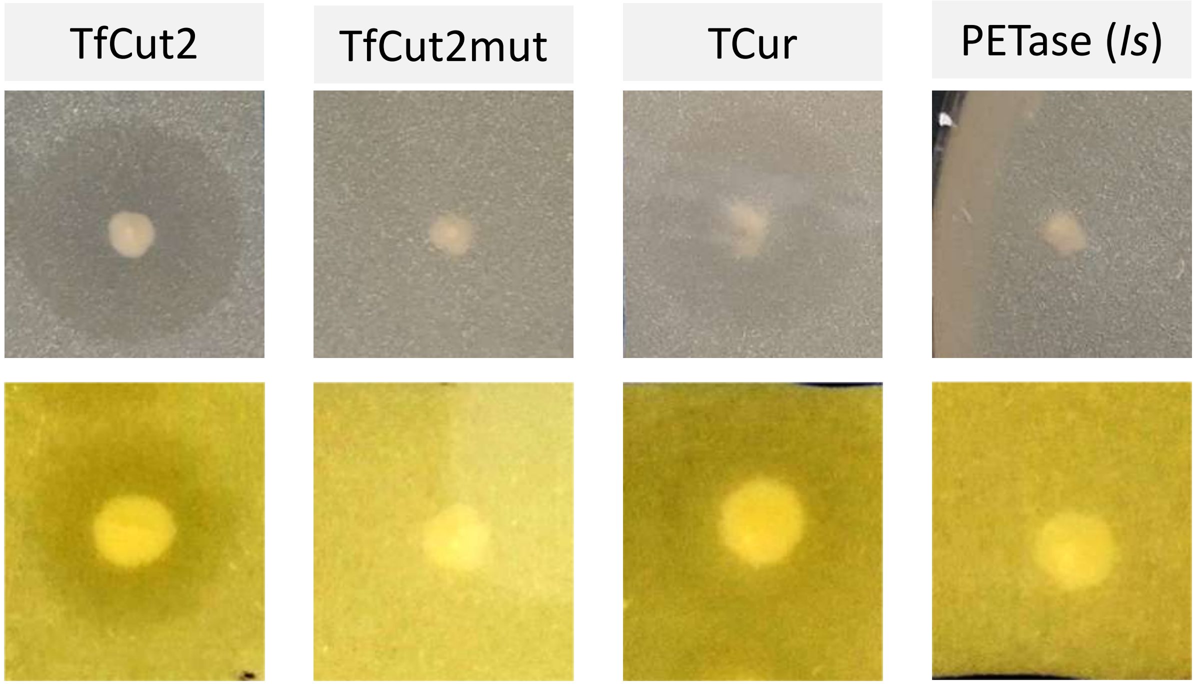
WP2: Engineering whole-cell PET degradation

- **Microbial degradation of PET**

Dr A. Banks

U. Abdulmutalib

Imperial College London

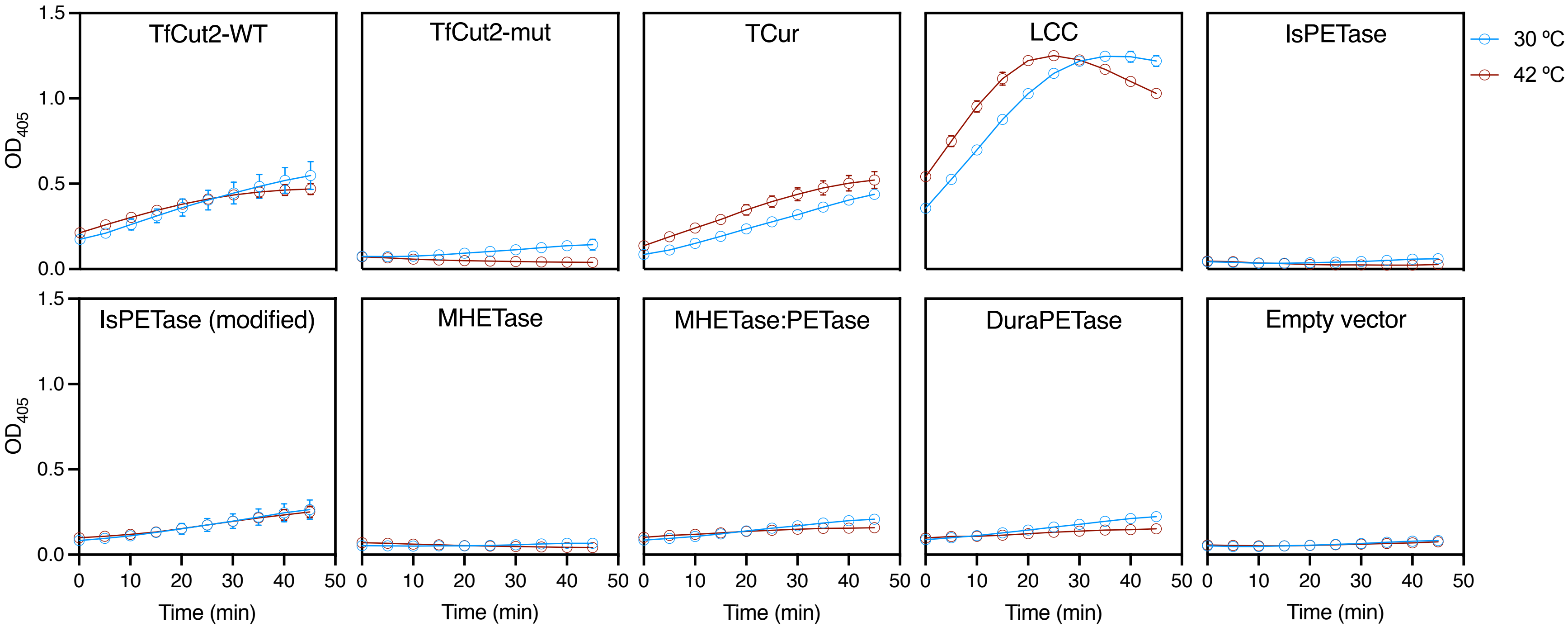


Pseudomonas putida KT2440

Pseudomonas umsongensis GO16

pNPB hydrolase activity in supernatants

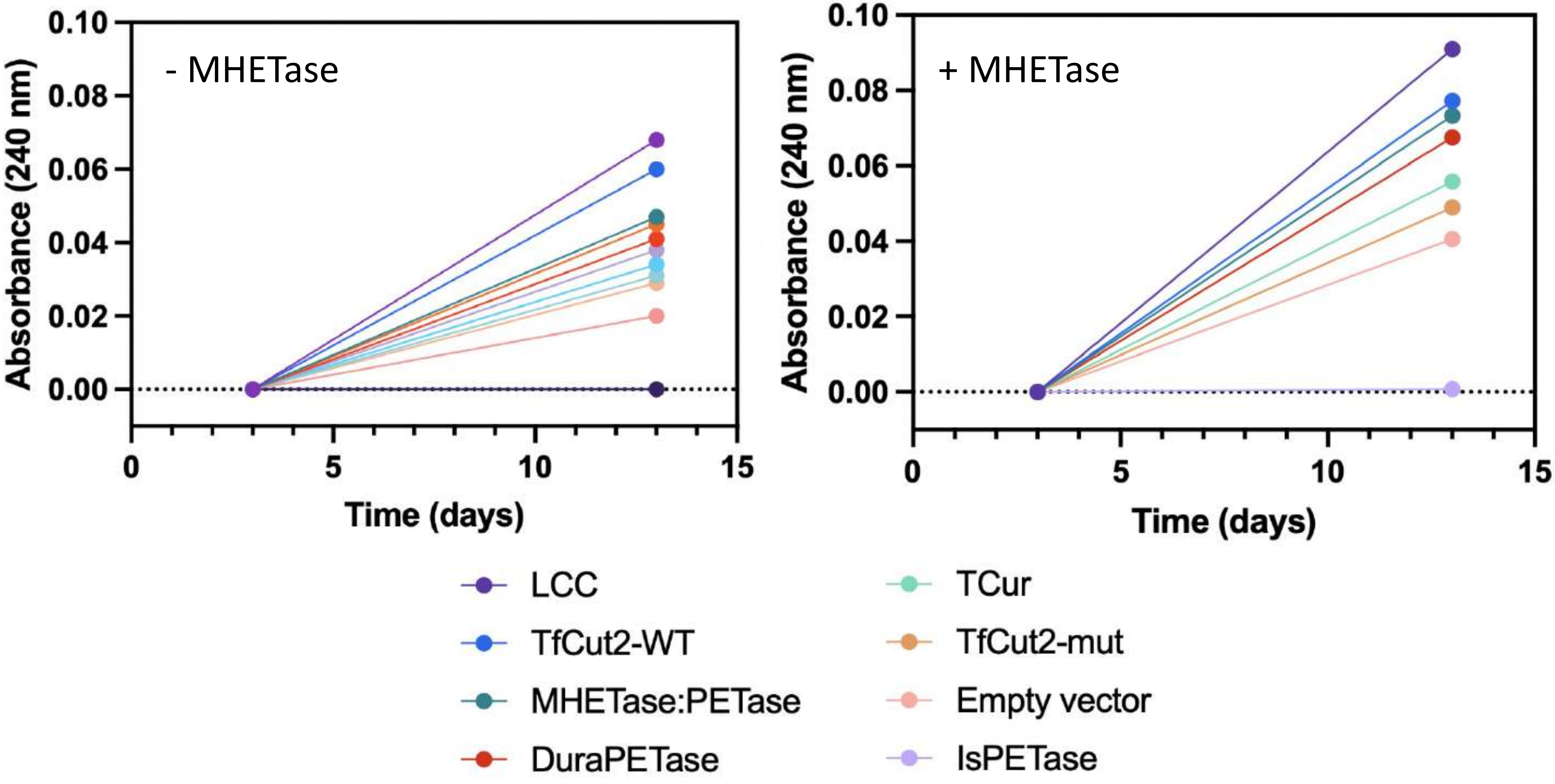
- pNPB assays at 30℃ (blue) or 42℃ (red)



- Thermophilic enzymes perform best
- Some activity detected in modified IsPETase variants and MHETase:PETase chimera
- Little temperature-dependent effect

PET film hydrolysis is low but detectable and MHETase helps

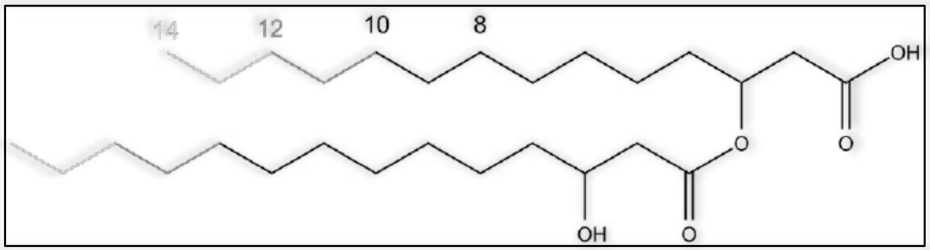
- Amorphous PET films incubated at 42℃

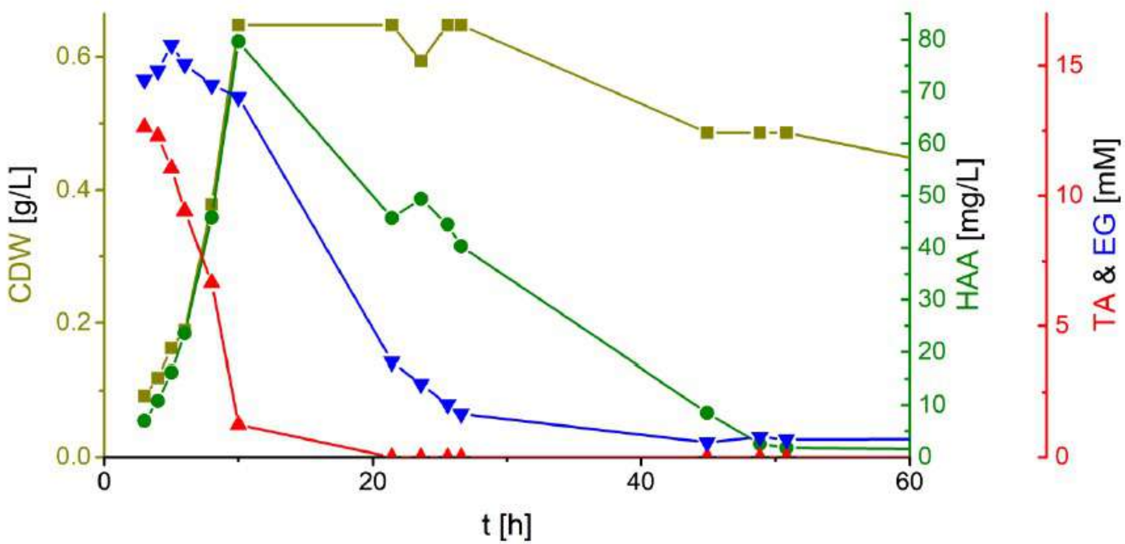


WP3: Metabolic engineering for synthesis of monomers

- **Production of monomers from PET**

Hydroxyalkanoic acids (HAAs) (AA and BDOs in progress)



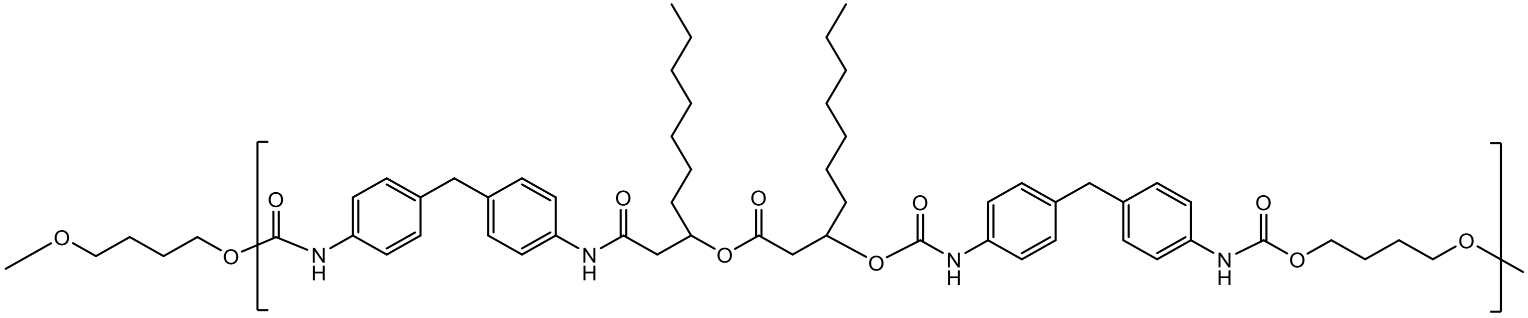


Dr T. Tiso Prof. L. Blank

- *P. putida* strain able to use TA and EG as carbon source
- HAAs produced from terephthalate and ethylene glycol resulting from PET hydrolysis

WP4: Synthesis of bio-PU

- **Synthesis of bio-PU (P4SB)**



- Copolymerization of 4,4′-diphenylmethylene diisocyanate, 1,4-butanediol, and HAA leads to a second generation poly(amide urethane)
- Formulations also include 1,4-BDO (good)
- 2,3-BDO possible but no suitable

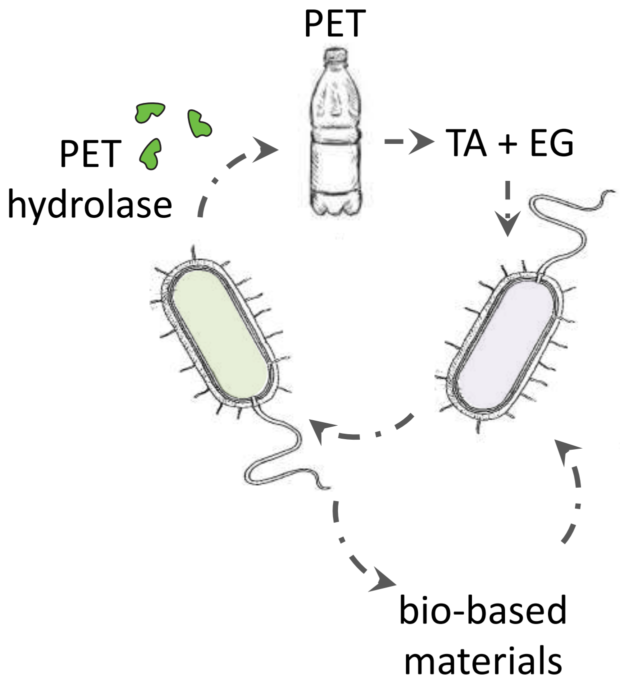
SOPREMA

Dr A. Sarbu

Eng. R. Perrin

Summary

- *We propose a circular approach for the microbial transformation of PET and PU in bio-based materials (bio-PU)*



- *Main goal:* ***Turn post-consumer PET into a microbial feedstock***
- *This can be done in vitro (with recombinant enzyme in a reactor)*
- *Or in vivo with whole organisms (individual or communities)*

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Responsible Research and Innovation (RRI)

MOPLACE

- *'anticipating and assessing potential implications and societal expectations of research and innovation to result in the design of inclusive and sustainable research and innovation'*

Dr J. Benton

Stakeholders working together throughout R & I process → R & I considers needs, values and expectations of society → R & I aligns process and outcomes with the needs, values and expectations of society.

https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

Responsible Research and Innovation (RRI)

Life cycle analysis

- MSc project: to conduct LCA on MIPLACE processes

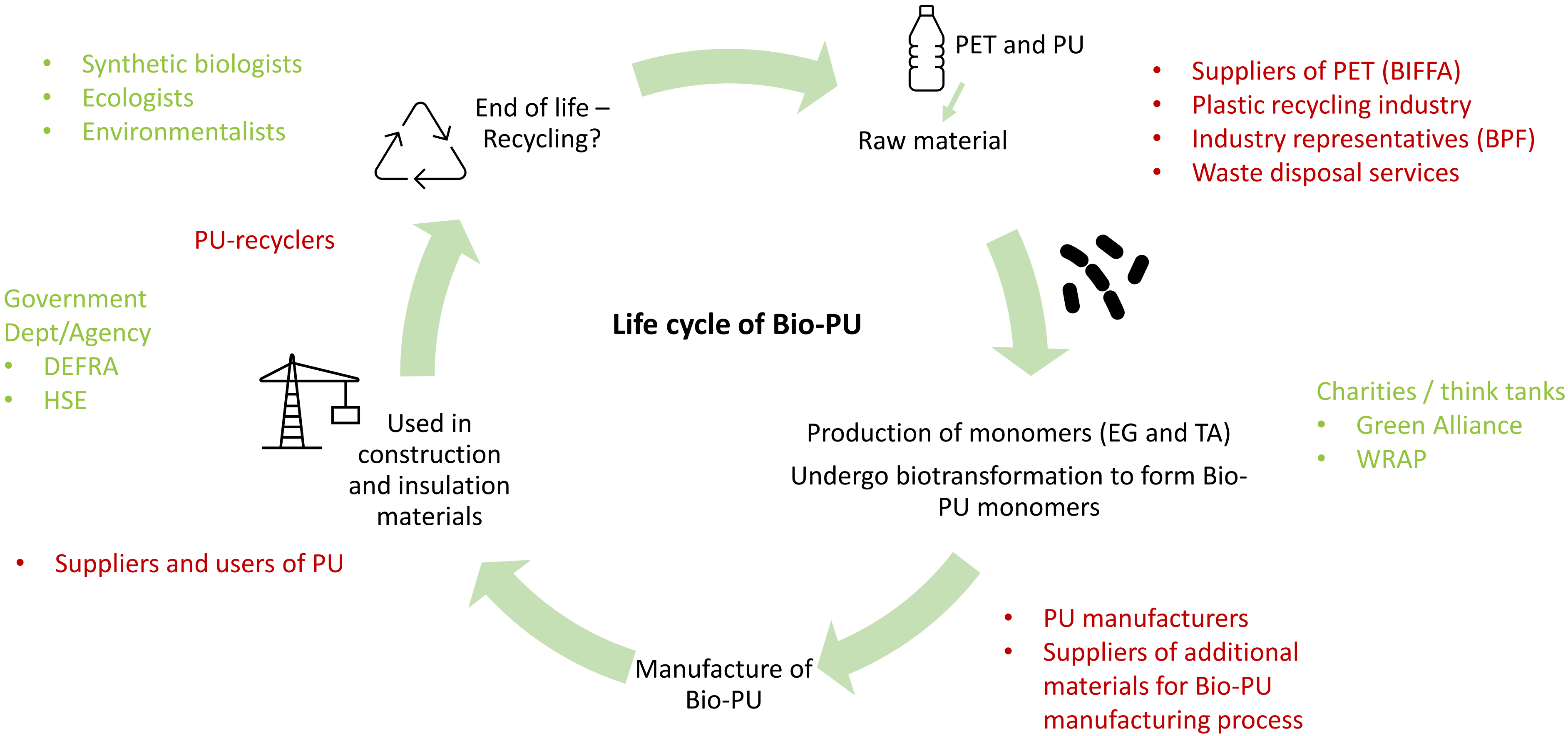
Stakeholder engagement

- LCA will also help identify stakeholders with an interest in MIPLACE technology
- Conduct semi-structured interviews with stakeholders as part of the stakeholder engagement process

Responsible Research and Innovation (RRI)

ERA CoBioTech — MIPLACE

- *Stakeholder engagement and semi-structured interviews*



Responsible Research and Innovation (RRI)

Synthetic Biology: Upcycling plastic waste for a circular economy

Website: www.miplacebio.com Twitter: @miplacebio

Plastic waste: A major global crisis

- 400 million tonnes of plastic produced globally each year
- Estimated 25% is incinerated and 56% going to landfill
- Global average recycling rates are 14-18%
- Plastic production poses huge environmental and health risks
- Use of fossil fuels for virgin plastics contributes to climate crisis

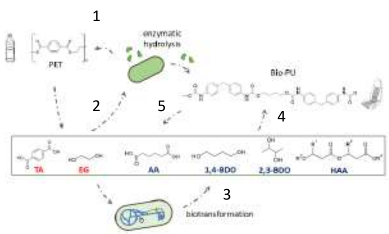
Plastics, the Circular Economy and Global Trade (WEF 2020)
UNEP 2020

What is synthetic biology?

- Employing engineering techniques to redesign organisms for beneficial applications such as solving problems within agriculture and the environment.
- In a nutshell, pieces of DNA from an organism, or novel DNA, are inserted into another organism's genome thus changing the genetic code and the activities of the recipient organism.

https://www.genome.gov/about-genomics/policy-issues/Synthetic-Biology

The MIPLACE approach for upcycling PET (and PU) plastic waste



Enzymatic hydrolysis of PET plastic waste (and PU) by microbes produces TA and EG monomers (1). These monomers support microbial growth (2) but also undergo biotransformation (3) into other monomers such as AA and 1,4-BDO. These, and other monomers, are used to synthesize Bio-PU (4) so achieving the upcycling of plastic waste.

Bio-PU is used as a construction and insulation material and can be recycled (5) at the end of its life demonstrating a circular approach for tackling PET waste.

PET: polyethylene terephthalate commonly used for single-use plastics especially in the beverage industry
PU: polyurethane (foams) used in insulation panels, carpet underlay, furniture and bedding, footwear

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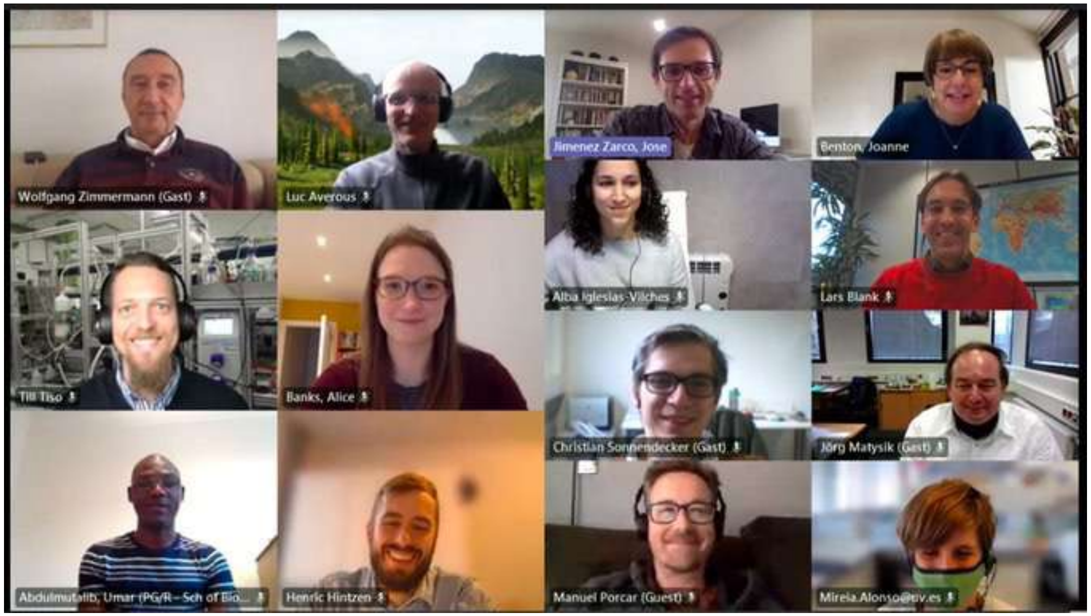

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Luc Averous
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UKRI Biotechnology and Biological Sciences Research Council
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