

DEEP PURPLE

DEEP PURPLE TECHNICAL SOLUTIONS

INTRODUCTION

The EU funded project DEEP PURPLE stands at the forefront of bioeconomy innovation, aiming to revolutionize urban waste management through sustainable and circular methodologies. By leveraging the untapped potential of **Purple Phototrophic Bacteria** (PPB), the project endeavors to convert municipal waste into **bio-based products**, thereby addressing critical environmental challenges while fostering economic growth. Initiated in response to the escalating waste management crisis, DEEP PURPLE embodies the EU's commitment to circular economy principles. This project is a beacon of hope in reducing reliance on fossil fuel-based products, generating jobs, and supporting the burgeoning organic market through the localized production of biofertilizers and bio polymers.

OVERVIEW

DEEP PURPLE aims to extract valuable resources from **urban biowaste** (organic fraction of municipal solid waste, wastewater and sewage sludge) using a **Multi-Platform Biorefinery**. This innovative approach, centered around PPB, focuses on recovering high-value compounds for the bio-based industry, including polyhydroxyalkanoates (PHA), ectoine and cellulose, demonstrated at three sites in Spain.

THE CHALLENGE

Currently 75% of the up to **138 million tons of urban biowaste** are **incinerated and landfilled** in the EU with huge ecological and economical costs.

THE OPPORTUNITY

Biowaste holds great potential as a source of renewable energy and recycled materials. Wastewater contains valuable components such as cellulose and nutrients that can be used as feedstock for many breakthrough applications.

MAIN OBJECTIVE

Convert biowaste into high value bio-products through a multi-platform photobiorefinery approach.

TECHNICAL OBJECTIVES

- **Valorize the organic fraction of municipal solid waste (OFMSW), wastewater and sewage sludge** into a sustainable biomass for marketable bio-based products.
- Create **biomass feedstock** for the bio-based industry.
- Implementation of a **multi-platform** concept (biomass, cellulose and biogas).
- First **PPB photobiorefinery** in the EU and the biggest world-wide.
- **Reduction of 60% of landfilled OFMSW.**
- **Recovery of 71% wastewater treatment plant (WWTP) solids.**

PARTNERS



DEMO SITES
FLEXIBLE
BIOREFINERY:
FEED-STOCK
PRODUCTION

MATERIALS &
PRODUCTS
DEMO SITES:

Construction
material

Bio-packaging

Bio-fertilizer

Bio-cosmetics



DEEP PURPLE

RECOVER ENERGY &
VALUABLE RESOURCES
from urban waste streams
IN PHOTOBIOREFINERIES
with the help of
PURPLE PHOTOTROPIC
BACTERIA

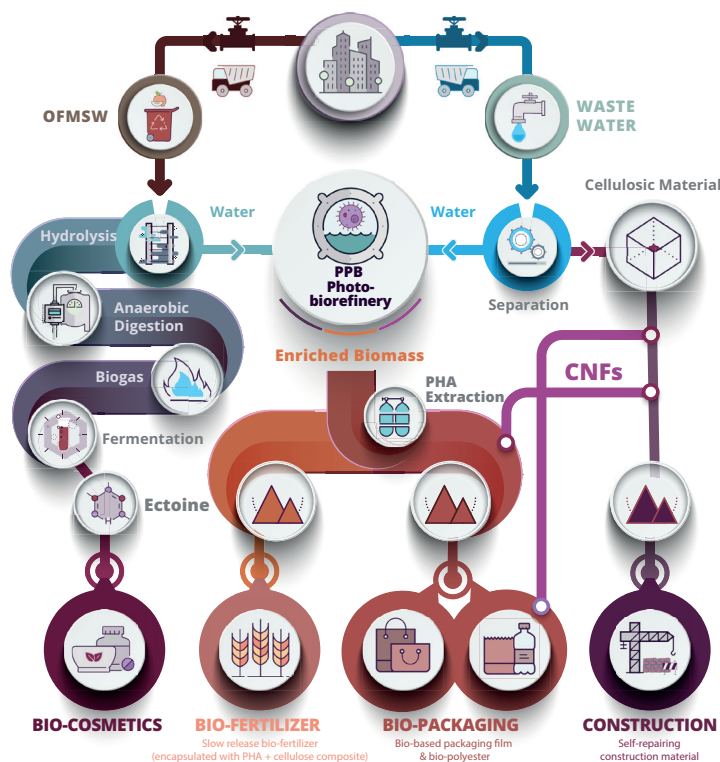


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BIO-BASED PRODUCTS WITHIN THE FRAMEWORK OF THE PROJECT

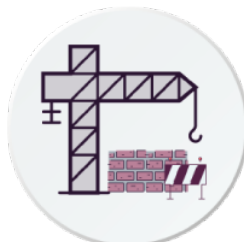
DEEP PURPLE successfully developed a range of **innovative bio-based products extracted from urban waste streams**.



Bio-packaging materials were developed using PHA combined with cellulose nano-fibers (CNF) at Novamont. The production process involved extracting PHA from enriched biomass by Activatec and obtaining CNF from wastewater sludge by ITENE. NaturePlast formulated and produced compounds with (PHA + CNF), and Novamont conducted pilot injection trials for cosmetic packaging.



Self-healing composites for construction were also produced using cellulose extracted from wastewater, which was transformed into CNF by ITENE. CNF were then employed in the production of advanced self-healing composites designed for the construction industry.



Slow-release pellet biofertilizer was developed by DEEP PURPLE at the AgrolInnovation International (Centre Mondial de l'Innovation - Roullier) plant in Saint-Malo, France. There, slow-release fertilizer was successfully produced and tested at an industrial pilot plant and later at a demo level.



Biopolyesters for film applications, based on 1,4 bio-butanediol, were derived from fermentable sugars obtained from cellulose. ITENE and Activatec optimized the formulations, while Novamont industrialized the production of 1,4 bio-butanediol, enabling the production of bio-based compounded polyesters suitable for sustainable film applications.



Cosmetic products containing extracted ectoine obtained from the OFMSW - this was extracted and purified by Activatec in the Biogas Platform. RNB used this ectoine as a raw material to develop cosmetic products, including various formulations that underwent stability testing. The most stable formulations were produced at pilot scale and validated in RNB's advanced production plant.



TECHNICAL PARTNERS AND THEIR ROLES

Activattec: runs a bio-based materials & production demo site in BioCity, Nottingham, UK which focuses on extracting and purifying PHA from PPB PHA-enriched biomass, ensuring lower cost, higher performance, and lower environmental impact compared to conventional methods. Activattec sends the PHA to ITENE, Novamont and NaturePlast for bio-packaging applications.

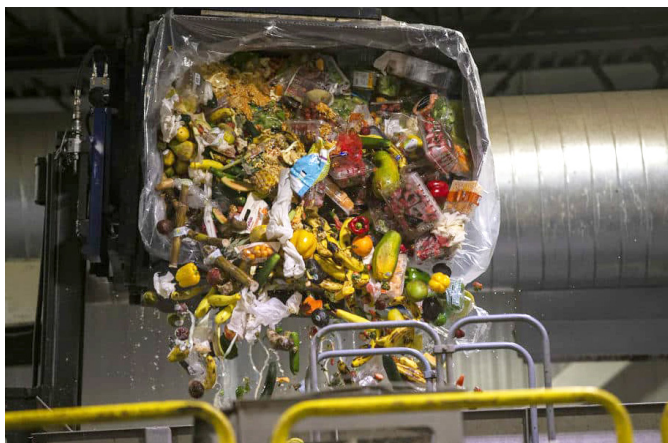
Aqualia: operates one of the first and largest solar-powered photobiorefinery based on PPB for wastewater treatment and nutrient-rich biomass. They also extracted cellulose from domestic wastewater for bio-packaging applications.

Brunel University: focuses on the use of CNF to produce self-healing composites for concrete bricks. They performed a circular assessment of the project's technologies.

Institute of Sustainable Processes (ISP): operates the bioreactor for ectoine production from biogas and extraction and purification of ectoine. The ectoine is sent to RNB for cosmetics formulation.

RNB: focuses on the incorporation of ectoine into their cosmetics formulation, contributing to the development of cosmeceutical products. They run a bio-based materials & production demo site in Valencia, Spain, focusing on the development of cosmetic products containing ectoine obtained from biogas in their laboratories.

FCC Medio Ambiente (FCC MA): is responsible for the provision of the OFMSW, further pre-treated by thermal hydrolysis to produce biogas for ectoine production.



Organic fraction of municipal solid waste (OFMSW)

ITENE: produces CNF and fermentable sugar solution from cellulose recovered from wastewater. ITENE runs a bio-based materials & production demo site at their facilities in Valencia, Spain: a research center specializing in packaging, transport, and logistics, plays a crucial role in developing materials for DEEP PURPLE. They use their facilities to produce CNF and collaborate in the development of bio-composites based on PHA and CNF. CNF are then used

by Brunel for self-healing composite formulation in concrete bricks, while the sugar solution is used by Novamont for production of 1,4 bio-butanediol (a precursor of biopolyesters).

NaturePlast: upscaling of selected formulations of PHA-CNF by ITENE and sending of composites to Novamont. NaturePlast plays a crucial role in formulating materials based on PHA and CNF and compounding them at lab and pilot scales contributing to the development of biodegradable packaging materials. Runs a bio-based materials & production demo site for bioplastic in Ifs, Normandy, France.

Novamont: production of mulching films and films for organic waste bags from bio-based polymers manufactured with 1,4 bio-butanediol. Novamont Group runs the Mater-Biotech demo facility in Adria, Italy, a bio-based materials & production demo site which validated the use of alternative sources of sugars, originating from urban biowaste, as feedstock for building blocks through direct fermentation. The resulting bio-based monomer is processed to produce biodegradable and compostable biomaterials for film applications.



1,4 bio-butanediol production plant

AgroInnovation International (Centre Mondial de l'Innovation - Roullier): run the fertilizer production plant in Saint Malo, France: a bio-based materials & production demo site for the production and testing of the slow-release biofertilizer pellets based on PPB biomass. An industrial pilot plant is used for production, with plans to upscale the process at the demo level.

University Rey Juan Carlos (URJC): are involved in the development of a multi-physics model for optimizing the control and operation of anaerobic raceways based on PPB. Additionally, URJC supervises the operation of anaerobic raceways and helped improve PHA extraction procedures from PPB biomass.

DEEP PURPLE DEMO SITES

Three DEEP PURPLE Multi-platform Biorefineries were constructed in bio-waste treatment facilities in Spain. These biorefineries aimed to recover resources from urban bio-waste, providing a sustainable supply of biomass feedstock for the production of high-value products for different industrial sectors.

Demo Site 1 - WWTP Linares (Jaén, Spain): this site is operated by Aqualia and owned by Linares Council. Here, DEEP PURPLE established the **first photobio-refinery based on the use of PPB**. This facility is operational since August 2022 and employs anaerobic photobioreactors to treat municipal wastewater and produce enriched PPB biomass as feedstock for slow-release fertilizers. Additionally, a filter solution was implemented to separate cellulose from wastewater, resulting in cellulose production.

Actions done:

- Implemented anaerobic photobioreactors treating 350 m³/d of wastewater.
- Produced enriched PPB biomass for slow-release fertilizers.
- Recovery of cellulose for CNF and fermentable sugar solutions.



Cellulose recovery plant



First and largest PPB-based photobiorefinery worldwide at WWTP Linares

Demo Site 2 – Biomethanation plant Las Dehesas (Madrid): DEEP PURPLE established the **first biorefinery for biogas conversion into ectoine**. This plant is operated by FFC MA and owned by Madrid City Council. The facility is operational since September 2022 and employs a bioreactor to produce ectoine from biogas and a thermal hydrolysis unit to treat the OFMSW for PHA production.

Actions done:

- Implemented ectoine-producing bioreactor treating 12 m³/d biogas.
- Conversion of methane into ectoine > 95%.
- Treatment of 164 tons of organic fraction of municipal solid waste in the thermal hydrolysis.



The hydrolysis thermal unit for OFMSW treatment at the biomethanation plant



The ectoine-producing bioreactor

Demo Site 3 - WWTP Rincón de Caya (Badajoz, Spain): here, DEEP PURPLE is establishing the **second photobiorefinery based on PPB**, operated by Aqualia and owned by Badajoz Council. Like Demo Site 1, this site aims to produce enriched PPB biomass.



Construction of the second PPB-based photobiorefinery at WWTP Rincón de Caya