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D1.5 FINAL REPORT ON THE MARKET ASSESSMENT OF CAP/FRP BASED BIOPRODUCTS AND CAFIPLA AS TECHNOLOGY IN THE BIO-ECONOMY EXPANSION

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This project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 887115. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

Bio-based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

BBI JU

Bio-based research and innovation action	
Call identifier	H2020-BBI-JTI-2019
Topic	BBI-2019-SO2-R2
Grand agreement number	887115
Project title	Combining carboxylic acid production and fibre recovery as an innovative, cost effective and sustainable pre-treatment process for heterogeneous bio-waste
	D1.5 Final report on the market assessment of CAP/FRP based bioproducts and CAFIPLA as technology in the bioeconomy expansion
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This deliverable has been prepared in the context of the project CAFIPLA funded from the Bio Based Industries Joint Undertaking (JU) under grant agreement No 887115. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and the Bio-Based Industries Consortium.

It must be stressed that the views expressed in this CAFIPLA Deliverable D1.5 FINAL REPORT ON THE MARKET ASSESSMENT OF CAP/FRP BASED BIOPRODUCTS AND CAFIPLA AS TECHNOLOGY IN THE BIO-ECONOMY EXPANSION are the sole responsibility of the authors and do not necessarily reflect the views of the BBI JU or the European Commission. The authors does not accept any liability for any direct or indirect damage resulting from the use of this CAFIPLA Deliverable D1.5 (2023), its content or parts of it. The results achieved, conclusions made, and recommendations given by the authors should not be interpreted as a political or legal signal that the BBI JU or the European Commission or any other political or legal institution intends to take a given action.

Please refer to this deliverable as:

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EXECUTIVE SUMMARY

The deliverable *D1.5 Final report on the market assessment of CAP/FRP based bioproducts and CAFIPLA as technology in the bio-economy expansion* highlights the relevance and impact of biowaste-derived materials in an expanding bioeconomy and demonstrates how novel value chains and markets are created from biowaste by the CAFIPLA technology.

SECTION 1 provides a comprehensive overview on the role of **biowaste as resource in a sustainable, circular bioeconomy** considering results from latest reports, material economics, legislation, strategies, current research as well as opinions from industry experts, foundations, and public authorities in this field.

SECTION 2 describes how CAFIPLA creates **novel value chains** from biowaste by combining carboxylic acid production and fibre recovery as an innovative, cost effective and sustainable pre-treatment process and how those **two platform products** can be converted into **valuable end products** such as PHA, caproic acid, microbial protein and fibre-based materials. Main findings from a comprehensive market assessment of the CAFIPLA end products are summarized (see *D1.1 Report on the initial market assessment of CAFIPLA*[1]).

SECTION 3 illustrates the successful **integration of the CAFIPLA pilot plant,** the “LOOP” [2] (TRL 5), at an intermunicipal waste treatment plant in Tenneville, Belgium (IDELUX Environnement). To this end, the **process schemes** behind the CAFIPLA technology for the synthesis of platform and end products are explained.

SECTION 4 showcases a selection of **final CAFIPLA products** generated at partner institutions including descriptions of process routes, product properties and market applications.

[1] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D1.1 (2021) – Report on the initial market assessment (Grant agreement ID: 887115). [Online]
[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

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ABBREVIATONS

Abbreviation	DESCRIPTION
AD	Anaerobic digestion
ATB	Leibniz Institut für Agrartechnik und Bioökonomie e.V.
CAP	Carboxylic acid platform
FRD	Fibres Recherche Développement
MCCA	Medium chain carboxylic acids
MP	Microbial protein
NADES	Natural deep eutectic solvents
OMSW	Organic municipal solid waste
PHA	Polyhydroxyalkanoate
SCCA	Short chain carboxylic acids
SCP	Single cell protein
UGent	University of Ghent

GOAL AND SCOPE OF THE REPORT

CAFIPLA develops a radically new approach to biomass use and pre-treatment for the creation of **new bio-economy value chains.** CAFIPLA will establish **two platforms** to achieve maximum valorisation of currently underused biomass streams into **bioproducts.**

The goal of the final market assessment report is to:

- Underline the impact of biowaste utilization in an expanding bioeconomy ⇨ **SECTION 1**
- Pinpoint economically promising CAFIPLA value chains and markets ⇨ **SECTION 2**
- Highlight the role of the CAFIPLA pilot plant as a successful demo case for waste valorisation ⇨ **SECTION 3**
- Showcase CAFIPLA product examples ⇨ **SECTION 4**

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SECTION 1

The Impact of Biowaste Utilization in an Expanding Bioeconomy

D1.5 FINAL REPORT ON THE MARKET ASSESSMENT OF CAP/FRP BASED BIOPRODUCTS AND CAFIPLA AS TECHNOLOGY IN THE BIO-ECONOMY EXPANSION

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BIOWASTE IS A KEY FEEDSTOCK IN A MORE CIRCULAR ECONOMY

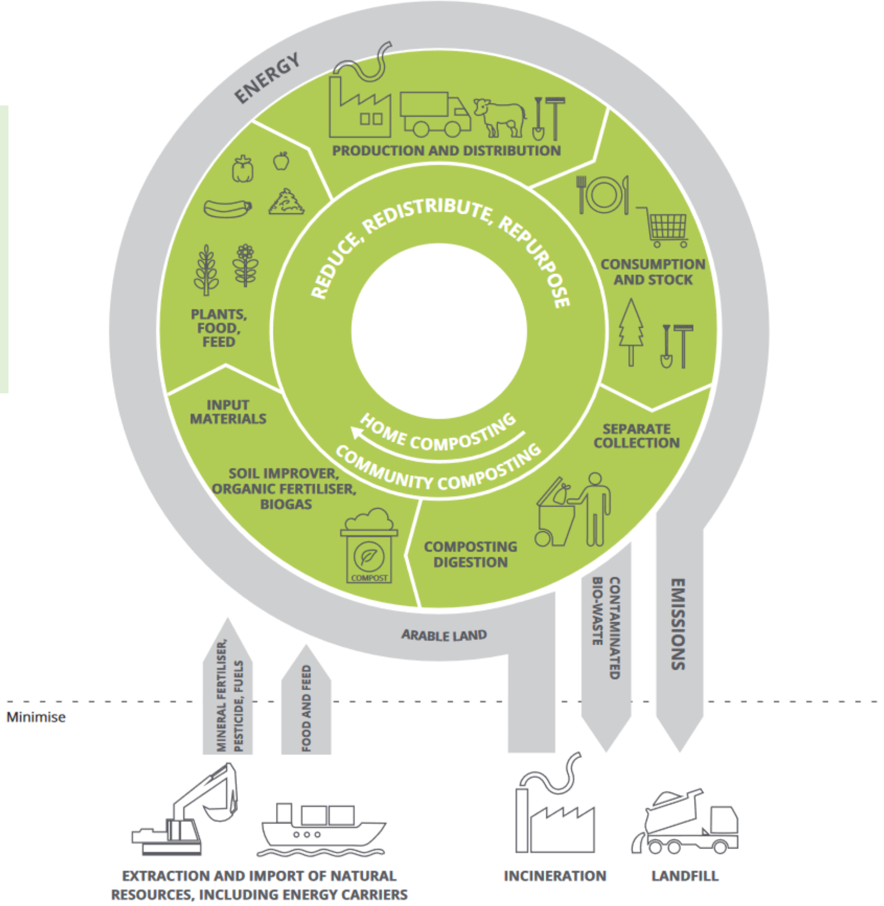
"Biowaste can play an important role in the transition to a circular economy, by both preventing its generation and capturing its potential as a source of valuable secondary resources."

European Environmental Agency[3]

Biowaste comprises[4] :

- biodegradable garden and park waste
- food and kitchen waste
- comparable waste from food-processing plants

⇨ Food waste accounts for ~60% of all biowaste!



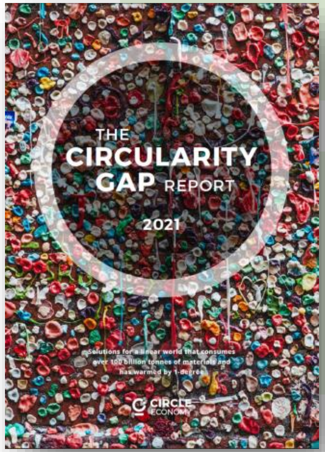
Adapted from [3]

[3] European Environment Agency (2020) Bio-waste in Europe turning challenges into opportunities, Report No. 04/2020
[4] European Commission (2008) Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives (Waste Framework Directive)

BIOWASTE IS A KEY ELEMENT OF THE CIRCULAR ECONOMY

"The importance of a functioning, future-focused waste management sector—that both collects and segregates waste at scale and produces high-quality secondary materials— is also generally overlooked. "

The Circularity Gap Report [5]



"For the past 200 years at least, the hallmark of global consumption and resource use can be aptly described as 'take-make-waste': a linear economy."

The Circularity Gap Report [5]

DISRUPT: KEY ELEMENTS OF THE CIRCULAR ECONOMY

The circular economy assumes dynamic systems, a process of transformation rather than a specific end-point. The DISRUPT model gives it direction.

- **D** — **Design For the Future:** Adopt a systemic perspective during the design process, to employ the right materials for appropriate lifetime and extended future use.
- **I** — **Incorporate Digital Technology:** Track and optimise resource use and strengthen connections between supply-chain actors through digital, online platforms and technologies.
- **S** — **Sustain & Preserve What's Already There:** Maintain, repair and upgrade resources in use to maximise their lifetime and give them a second life through take-back strategies, where applicable.
- **R** — **Rethink the Business Model:** Consider opportunities to create greater value and align incentives through business models that build on the interaction between products and services.
- **U** — **Use Waste as a Resource:** Utilise waste streams as a source of secondary resources and recover waste for reuse and recycling.
- **P** — **Prioritise Regenerative Resources:** Ensure renewable, reusable, non-toxic resources are utilised as materials and energy in an efficient way.
- **T** — **Team Up to Create Joint Value:** Work together throughout the supply chain, internally within organisations and with the public sector to increase transparency and create shared value.

[5] Circle Economy (2021) The Circularity Gap Report 2021. Available from www.circularity-gap.world

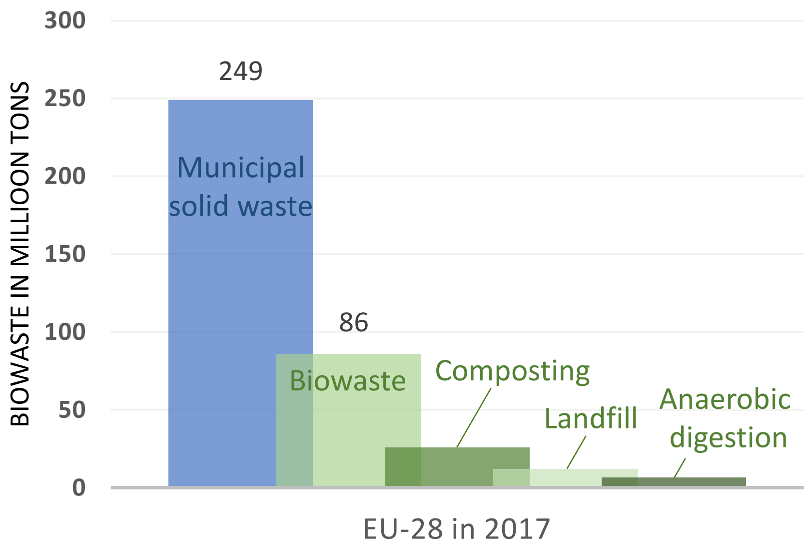
BIOMASS WILL PLAY AN ESSENTIAL ROLE FOR MATERIAL PRODUCTION EVEN THOUGH DEMAND AND COMPETITION WILL INCREASE

- Current climate scenarios risk an over-reliance on biomass resulting in a predicted **biomass gap** by 2050 of **40-70%.**
- Traditional bioenergy applications are set to be **outcompeted** by new options such as electrification and hydrogen.
- The future use of biomass will focus on materials and specialised niches as particularly **high-value** areas such as **fibres, chemicals and textiles.**
- Nearly **all petrochemical products** can in principle be produced from basic chemicals **derived from biomass** including plastics, solvents, fertilizers, fibres etc.
- The sustainable generation and **efficient cascade utilisation of biogenic resources** are in the centre of, both European and National policies, in which material use is generally prioritised over energetic use (e.g., see [7]).

Derived from [6]

[6] Material Economics (2021). EU Biomass Use In A Net-Zero Economy - A Course Correction for EU Biomass
[7] BMUV (2022). Eckpunkte für eine Nationale Biomassestrategie (NABIS) [Online]

BIOWASTE IS AN ABUNDANT, CURRENTLY UNDERUSED FEEDSTOCK



- Biowaste is the **largest single component** of municipal solid waste in the EU[3].
- Biowaste accounts for **34% of municipal solid waste.**
- Only 7.5% is currently treated via anaerobic digestion.
- Worldwide biowaste generation will increase from 650 million tons (2017) up to worldwide ~**1.1 billion tons** in 2025.
- Currently only 40% of biowaste is collected and treated separately in Europe.

Derived from [8-10]

> "According to the 2018 EU Bioeconomy Strategy, cities should become major circular bioeconomy hubs, mainly by valorising their urban bio-waste and wastewater resources into bio-based products."
>
> *EU Bioeconomy Strategy Progress Report*[8]

[8] European Commission (2022) EU Bioeconomy Strategy Progress Report. European Bioeconomy Policy: Stocktaking and future developments
[9] EUROSTAT 2016
[10] Hoornweg D. et al., 2012. What a waste – a global review of solid waste management. The World Bank, Urban development series knowledge papers.

BIOWASTE COLLECTION AND CONVERSION IS ESSENTIAL TO MITIGATE ITS IMPACT ON CLIMATE CHANGE

- Biodegradable waste is a key source of greenhouse gas emissions from **landfill sites**[3]
- Around **3% of total EU GHG emission**s are caused by landfills[11]
- The estimated GHG emissions related to food losses and wastes in the EU-28 are responsible for **15-22% of the total life-cycle emissions** [12,13]

Consequently:

- The EU targets to **recycle 65% of municipal waste** by 2035[4]
- The EC's bioeconomy strategy aims to **cut food waste by 50%** by weight by 2030 focusing on the prevention of avoidable edible food waste [14]
- Landfilling of separately collected biowaste was banned (Landfill Directive [15])

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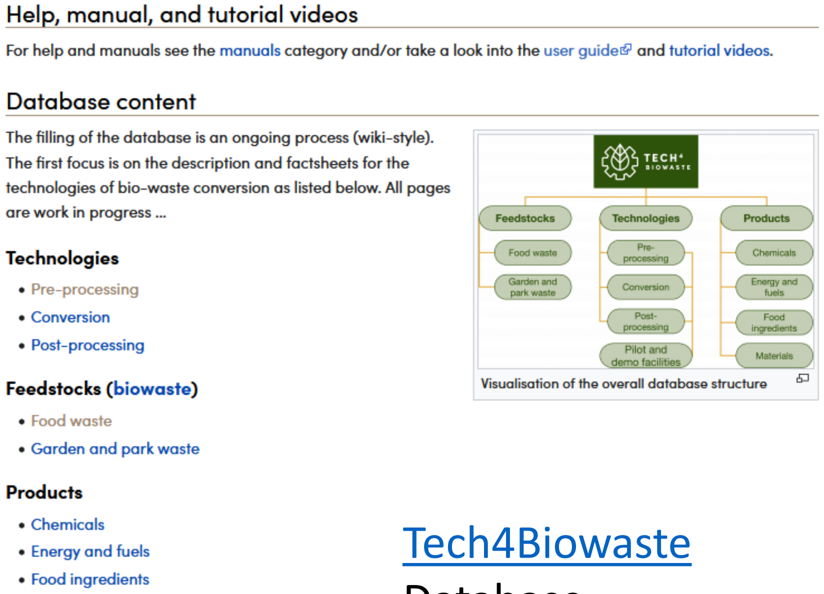
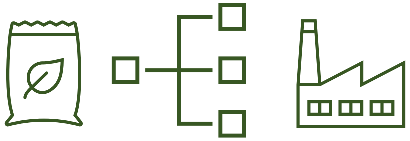
[11] EEA, 2019a, Annual European Union approximated greenhouse gas inventory for the year 2018, EEA Report, No 16/2019, European Environment Agency
[12] Scherhaufer, S., et al., 2015, Criteria for and baseline assessment of environmental and socio-economic impacts of food waste — final report, Wageningen, The Netherlands
[13] Scherhaufer, S., et al., 2018, 'Environmental impacts of food waste in Europe', Waste Management 77, pp. 98-113.
[14] EC, 2018a, A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment, EC Directorate-General for Research and Innovation, Brussels
[15] EC, 2008, Green Paper on the management of bio-waste in the European Union (COM(2008) 811 final).

BIOWASTE UTILISATION TECHNOLOGIES CREATE NOVEL VALUE CHAINS BY LINKING FEEDSTOCK SUPPLIERS AND MANUFACTURERS

- Knowledge gap about increasing biowaste utilisation potential and innovative approaches needs to be bridged
- Bringing together biowaste collectors, technology providers and biomanufacturers is crucial to transition towards a more circular economy.
- Tech4Biowaste builds a dynamic database of emerging and established technologies for biowaste utilization[14]



Tech4Biowaste Database



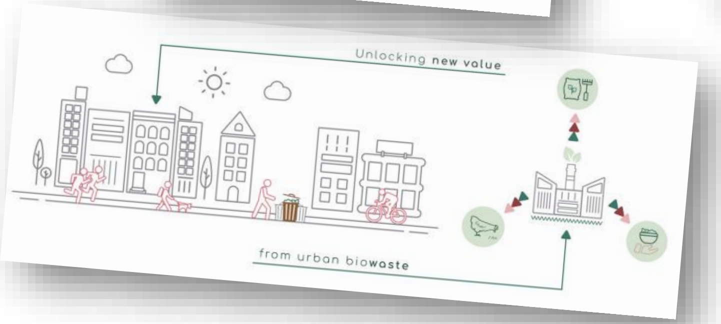
"The Tech4Biowaste project aims to provide the bio-based industry with a complete overview of existing and emerging technologies with a Technology Readiness Level (TRL) 4 and higher for biowaste utilisation and valorisation."

European Research Project Tech4Biowaste[16]

[16] Horizon 2020 Project (2021-2023) Tech4Biowaste: A dynamic database of relevant technologies of bio-waste utilization (Grant agreement ID: 101023200).

BIOWASTE UPCYCLING IS KEY TO CREATE AN URBAN CIRCULAR BIOECONOMY

- A fast transition towards a circular bioeconomy is particularly needed in cities[17]. At this, upcycling of biowaste plays a central role to create sustainable value chains in the urban bioeconomy.
- However, novel waste valorisation concepts for the urban bioeconomy require new models of regulations and governance and increased collaboration between various sectors and stakeholders[18].
- Multiple European R&D projects demonstrate how biowaste technologies can be successfully implemented in city thereby promoting a circular urban bioeconomy (see, e.g., [19-21]).



"Cities play a key role in the transition to a circular economy. Currently, cities are grappling with the effects of our current take-make-waste, linear economy. They consume over 75% of natural resources, produce over 50% of global waste, and emit 60-80% of global greenhouse gases. At the same time, cities continue to grow; by 2050, two-thirds of us will live in cities."

Ellen MacArthur Foundation[17]

[17] Ellen MacArthur Foundation (2021) Video Episode 34: How cities lead the transition to a circular economy [Online]; Circular cities: thriving, liveable, resilient [Online]
[18] B. Mahjoub and E. Domscheit (2020) Chances and challenges of an organic waste-based economy, Curr. Opin. Green Sustain. Chem., https://doi.org/10.1016/j.cogsc.2020.100388
[19] Horizon 2020 Project (2018-2022) VALUEWASTE: Unlocking new VALUE from urban bioWASTE (Grant agreement ID: 818312).
[20] Horizon 2020 Project (2017-2022) URBIOFIN: Demonstration of an integrated innovative […] (Grant agreement ID: 745785).
[21] Horizon 2020 Project (2020-2024) hoop: Hub of circular cities boosting platform to foster investments for the valorisation of urban biowaste and wastewater (Grant agreement ID: 101000836).

BIOWASTE-BASED NOVEL PRODUCTION ROUTES ARE ESSENTIAL TO DECREASE DEPENDENCY ON FOSSIL RESOURCES

"**Bio-based fertilisers are a promising alternative** or supplement to mineral and fossil-based fertilisers. They can be produced using **circular bioeconomy approaches**, from renewable bio-based sources, such as urban waste, […], or other industrial sidestreams, turning a problem into a new opportunity and closing the nutrients cycle."

Circular Bio-based Europe Joint Undertaking[22]

"The *PlasticsToBio* concept shows that within just ten years, **most fossil-based plastics could be replaced** with bio-based materials."

Tomi Nyman, AFRY Principal Management Consulting[23]

"By valorising OFMSW* as feedstock, we obtain **innovative biodegradable and compostable bioplastics** promoting new biorefinery models."

Marta Saccomanno, Biotechnology researcher at Novamont[24]

*Organic Fraction of Municipal Solid Waste

[22] Environmentally friendly fertilisers to cut Europe's dependency on imported fossil resources | Circular Bio-based Europe Joint Undertaking (CBE JU)[Online].
[23] PlasticsToBio programme | AFRY Management Consulting [Online].
[24] Horizon 2020 European Research Project (2018-2022) SCALIBUR: Scalable Technologies for Bio-Urban Waste Recovery (Grant agreement ID: 817788).

BIOWASTE-BASED NOVEL PRODUCTION ROUTES ARE ESSENTIAL TO ESTABLISH A COMPETITVE EUROPEAN BIOECONOMY

THE WHITE HOUSE

SEPTEMBER 12, 2022

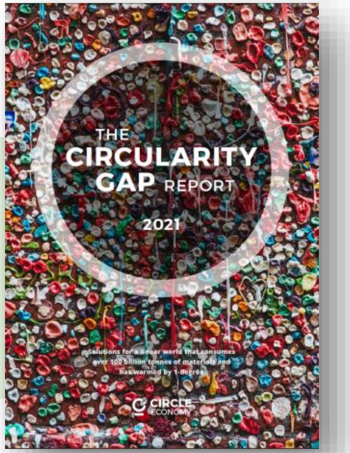
Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy

"[The Executive Order calls for] a **whole-of-government approach** to advance **biotechnology and biomanufacturing** towards innovative solutions in health, climate change, energy, food security, agriculture, supply chain resilience, and national and economic security."

Executive Order of the White House[25]

"As the largest economy— and the biggest emitter—in the profile, **China steps to the fore as the circular economy leader**, exhibiting a range of interventions from building up recycling infrastructure and eco-industrial parks, to implementing low-carbon agriculture techniques and reusing organic waste."

The Circularity Gap Report[5]



A new initiative for building a more competitive Europe: EuropaBio announces Biomanufacturing Platform

14/11/2022

"As Europe makes the most significant societal and industry transition since the industrial revolution, biomanufacturing is an essential component. And we are not alone. The **recent US White House Executive Order on biomanufacturing sends a global message** that it is central to a resilient and secure economy and that coordinated policy actions underpin successful delivery".

Dr. Claire Skentelbery, EuropaBio Director General[26]

[25] The White House (2022) Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy [Online]
[26] EuropaBio Press release (2022) EFIB Vilnius Statement [Online]

TAKEN TOGETHER, BIOWASTE…

(1) is an essential feedstock to contribute to a more circular bioeconomy.

(2) can play an important role in mitigating the predicted biomass gap in Europe.

(3) has a substantial but underused potential available in Europe and beyond.

(4) utilisation technologies for bioproduction will become increasingly important.

(5) collection and treatment will improve significantly in the next decade due to changes in legislation and society.

(6) utilization can contribute to mitigate climate change by reducing emissions from landfills.

(7) utilization can help to reduce dependency on fossil resources.

(8) utilization is needed to stay competitive in Europe.

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SECTION 2

CAFIPLA Value Chains and Markets

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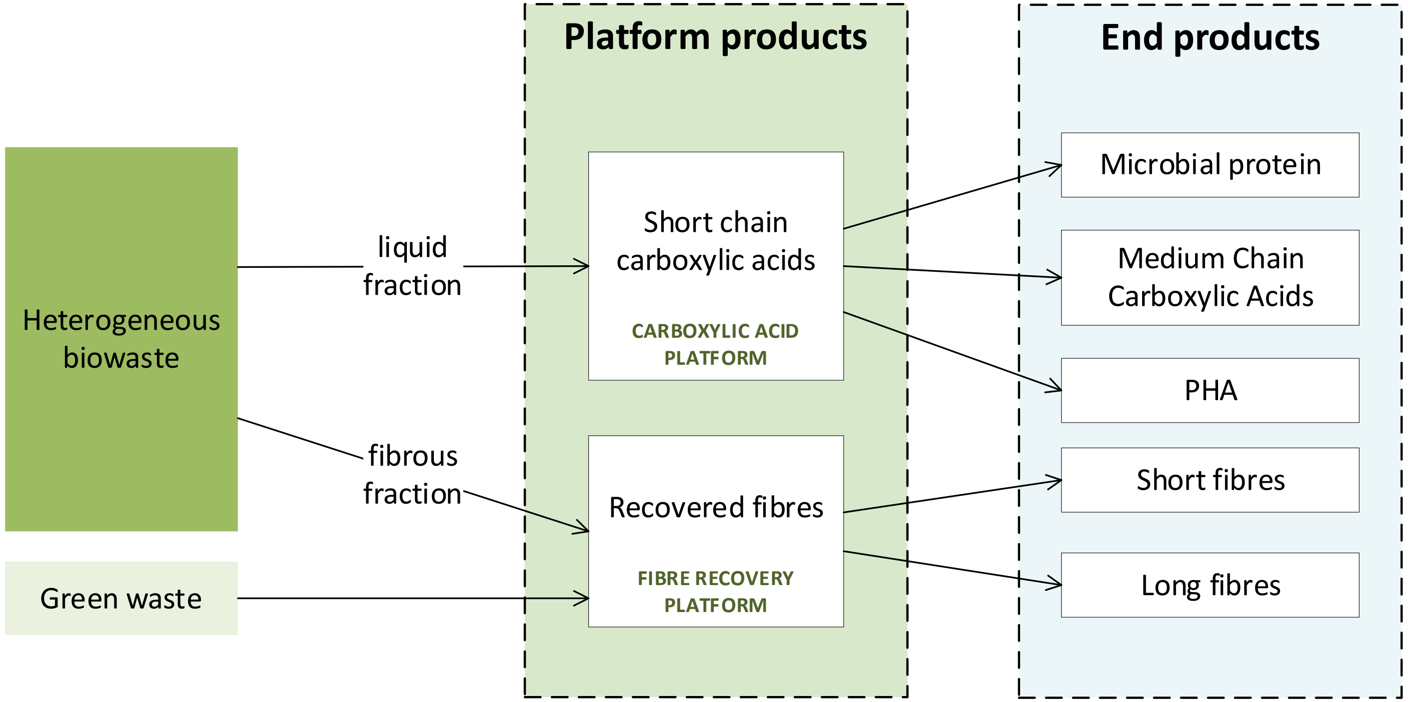
CAFIPLA TURNS BIOWASTE INTO VALUABLE PLATFORM PRODUCTS AND END PRODUCTS



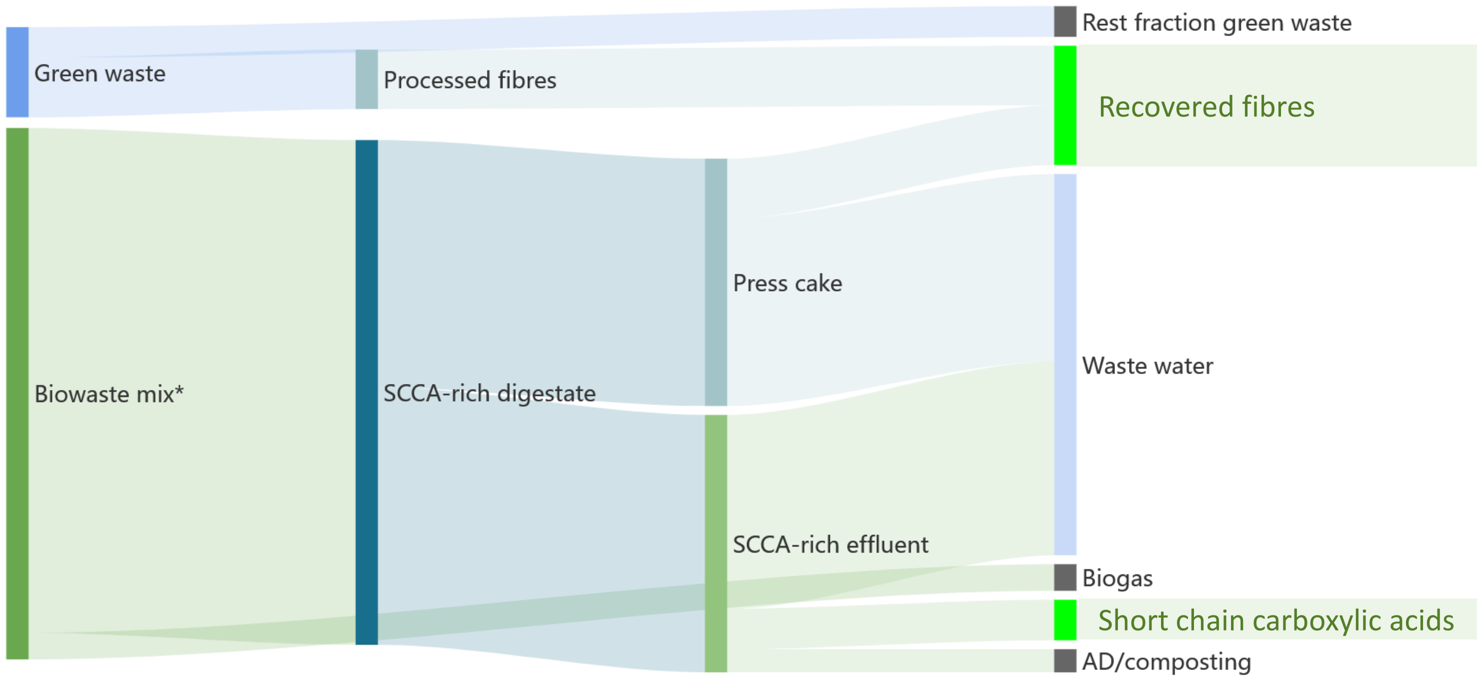
In a primary valorisation step, heterogenous biowaste and green waste are converted **into two platform products**:

- Short chain carboxylic acids (SCCA) via the Carboxylic acid platform (CAP)
- Recovery of fibres via the Fibre recovery platform (FRP)

In a second valorisation step, the platform products are converted into a broad range of **valuable bio-based end products**.

⇨ Combining **carboxylic acid production** and **fibre recovery** as an innovative, cost effective and sustainable pre-treatment process

CAFIPLA PLATFORM PRODUCTS ARE GENERATED WITH HIGH CONVERSION YIELDS



*80 wt% heterogenous biowaste + 20 wt% water

Fibres are recovered from both, green waste as well as from the press cake of a SCCA-rich digestate fraction obtained from the tailored CAFIPLA dark fermentation process of heterogenous biowaste.

Short chain carboxylic acids are obtained by pressing, decanting, filtration and concentration of the SCCA-rich digestate fraction.

All fractions not valorised via the CAFIPLA platform are **fed back into conventional valorisation routes** such as AD or composting.

⇨ See SECTION 3: The CAFIPLA Pilot Plant: A Successful Demo Case for Waste Valorisation

CAFIPLA END PRODUCTS HAVE HIGH MARKET POTENTIAL

Main findings of the initial market assessment for CAFIPLA end products:

- The CAFIPLA technology represents an attractive utilization option for biowaste, especially for biogas plant operators.
- Current and future technical as well as societal developments will push the use of such technologies also in the future.
- The market attractiveness of the products will benefit from changing framework conditions (e.g., increased awareness of environmental and health issues, legal framework, etc.)
- All identified target markets will grow in near future.
- The technologies developed and the usage of widely available, extremely cost-effective feedstocks will lead to competitive product prices, which also promotes a future market permeation.


CAFIPLA

PRESS Release No.2

27TH OF AUGUST 2021

MARKET ANALYSIS DEMONSTRATES: BIO-BASED PRODUCTS FROM MIXED BIOWASTE ARE PROFITABLE

The market analysis conducted as part of the BBI-funded CAFIPLA project, which is developing a new technology for obtaining biobased chemicals and products from biowaste, shows high potential for four customized biobased products in the initial economic assessment.

Source: IDELUX

The market assessment included consideration of CAFIPLA processes and four potential future products. CAFIPLA target products include polyhydroxyalkanoates (PHA), which can be used as biobased and biodegradable plastics or bio composites. Medium chain carboxylic acids (MCCA) in the form of MCCA bio-oil can be used as antimicrobial feed additives. Further, microbial proteins considered in CAFIPLA offer good possibilities as slow-release fertilizers or food and feed additives. Reinforced natural fibres have high environmental benefits and are relevant for the insulation and construction market segments.

CAFIPLA End products	Suggested application
Polyhydroxyalkanoate (PHA)	Biodegradable and bio-based plastics, bio-composite
Medium chain carboxylic acids (MCCA)-Bio-oil, caproic acid	Antimicrobial feed additive, bulk chemical
Microbial protein (MP)	Slow-release fertilizer, food additive
Fibres	Wood plastic composite, insulation material

⇨ See CAFIPLA Deliverable D1.1 – Report on the initial market assessment of CAFIPLA as biowaste valorisation strategy and pre-treatment to feed the bio economy with CAP/FRP-based bioproducts, February 2021.[19]

[1] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D1.1 (2021) – Report on the initial market assessment (Grant agreement ID: 887115). [Online]

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VALUE CHAIN ANALYSIS: RECOVERED FIBRES FROM THE FIBRE RECOVERY PLATFORM

Production and implementation:

- Production of **specific fibres** (size range from micrometer to centimeter) from urban biowaste, green waste or paper waste for dedicated applications in **thermoplastic and insulation markets**.
- Implementation of the technology in **existing fibre production plants** or in new, **dedicated plants** able to valorise biowaste.

Value proposition:

- The technology targets **multiple market segments** e.g., public bodies and municipalities, building and transport industry (e.g., insulation, compounds etc.), agriculture and horticulture.
- Fibres recovered from biowaste help fulfill the **market demand** for natural fibres to produce biobased materials and offer an **environmentally friendly** and **sustainable alternative** to a wide range of fibre applications e.g., (i) by valorizing low-cost carbon from **local resources**, (ii) by developing lightweight materials for transportation and (iii) by offering materials with the **same properties** (e.g., insulation) without putting more stress on agricultural production.
- Biobased materials based on renewable fibres represent a market with **strong development** and have significant **penetration rates** in the field of plastics (10% market share) [ADEME], the insulation (9%) or concrete (0.5%).
- The value of the end-products is **2.5 - 3 times higher** than the actual valorization of the biowastes aimed in CAFIPLA project, thus creating real perspectives for this kind of resources.

⇨ See SECTION 4: CAFIPLA Product Showcases

VALUE CHAIN ANALYSIS: SCCA-DERIVED PRODUCTS FROM THE CARBOXYLIC ACID PLATFORM

The conversion of **SCCAs** into a variety of high-value end-products was demonstrated by CAFIPLA partners that are experts in their fields.

All CAFIPLA end-products exhibit considerable advantages compared to competing products:

- **PHA** derived from the CAFIPLA technology exhibits enhanced mechanical properties and improved processability.
- **PHA and fibres** obtained from the CAFIPLA process can be combined to yield bio-composites with tailor-made properties.
- **Caproic acid** obtained via a lactic acid chain elongation route results in below-average market prices and offers an environmentally-friendly replacement of CA made from palm kernel oil (e.g., advantages regarding land use, GHG emissions)
- **Microbial protein** can be produced at reduced production costs and with tailored MP-composition (e.g., protein content and amino acid profile)
- By fine-tuning down stream processing, **Microbial protein** can be obtained that complies with specific regulations needed for usage as feed-additive or fertilizer.

Market prices [€/tonne]

PHA: 4000 - 5000

Caproic acid

- Unrefined: 830
- Refined: ~1700 - 3700

Microbial Protein (MP)

- Dried SCP: ~5000 - 13400
- Dried MP (Bacteria): ~1000 -1100
- Fishmeal: 1203
- Soybean meal: 414

Derived from [1]

⇨ See SECTION 4: CAFIPLA Product Showcases

[1] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D1.1 (2021) – Report on the initial market assessment (Grant agreement ID: 887115). [Online]

CAFIPLA OFFERS HIGHER VALUE COMPARED TO EXISTING VALORISATION APPROACHES

CAFIPLA offers an economic alternative to conventional sugar-based biorefinery concepts and anaerobic digestion plants. Being based on heterogenous biowaste as alternative carbon source, the CAFIPLA technology will **complement or replace existing valorisation approaches** by generating end products with **3 - 15 times higher value per ton** of input material compared to regular anaerobic digestion plants and by avoiding energy and chemical costs for sugar extraction.

The CAFIPLA technology can be implemented:

- as **stand-alone biorefinery**, converting heterogenous biowaste into bio-based end products.
- integrated with existing waste treatment facilities e.g., **anaerobic digestion plants**, for the generation of platform products or end product.
- integrated with existing **biorefinery sites** to complement a circular product portfolio by technology integration.

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SECTION 3

The CAFIPLA pilot plant:
A successful demo case for waste valorisation

D1.5 FINAL REPORT ON THE MARKET ASSESSMENT OF CAP/FRP BASED BIOPRODUCTS AND CAFIPLA AS TECHNOLOGY IN THE BIO-ECONOMY EXPANSION

This project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 887115. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

Bio-based Industries Consortium

Horizon 2020
European Union Funding
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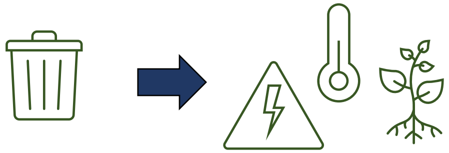
BBI JU

IDELUX ENVIRONNEMENT: TEST SITE FOR THE CAFIPLA PILOT

- IDELUX Environnement is an intermunicipal, public non-profit company in Belgium
- Household waste management in the province of Luxembourg:
  - Area: 4,400 km²
  - Inhabitants: 350,000
  - Plants: Habay (Alternative fuels) and Tenneville (Biogas & electricity)
- Treatment of **O**rganic **M**unicipal **S**olid **W**aste (OMSW) in Tenneville: **A**naerobic **D**igestion (AD) plant with DRANCO reactor
  - OMSW: 35 000 t/a
  - Green waste: 20-25 000 t/a
  - Biogas: 5-6 Mio. Nm³
  - Electricity: 8-10 000 000 kWh/a
  - Heat: 7 500 000 kWh/a
  - Digestate: 25 000 t/a



Derived from [2]

Headquarter in Arlon, Belgium

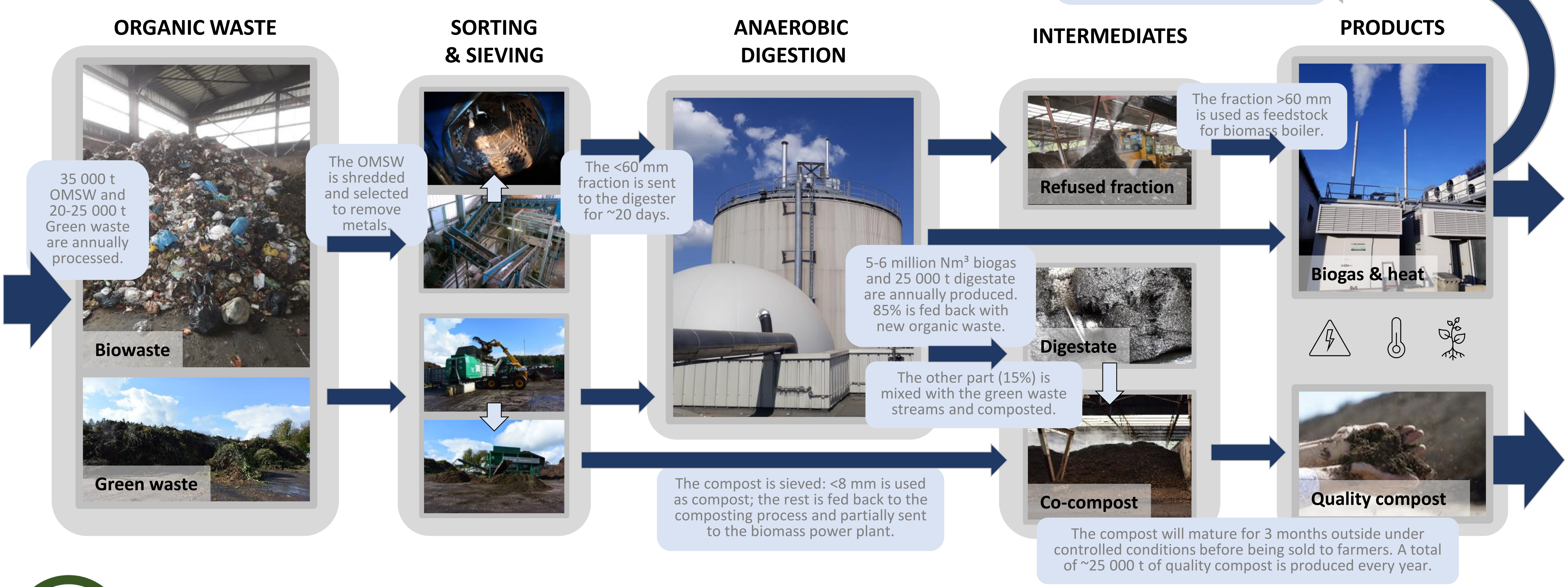
Waste treatment site in Tenneville, Belgium

[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

Picture source: IDELUX

BIOWASTE: TREATMENT PROCESS AT TENNEVILLE SITE

Derived from [2]



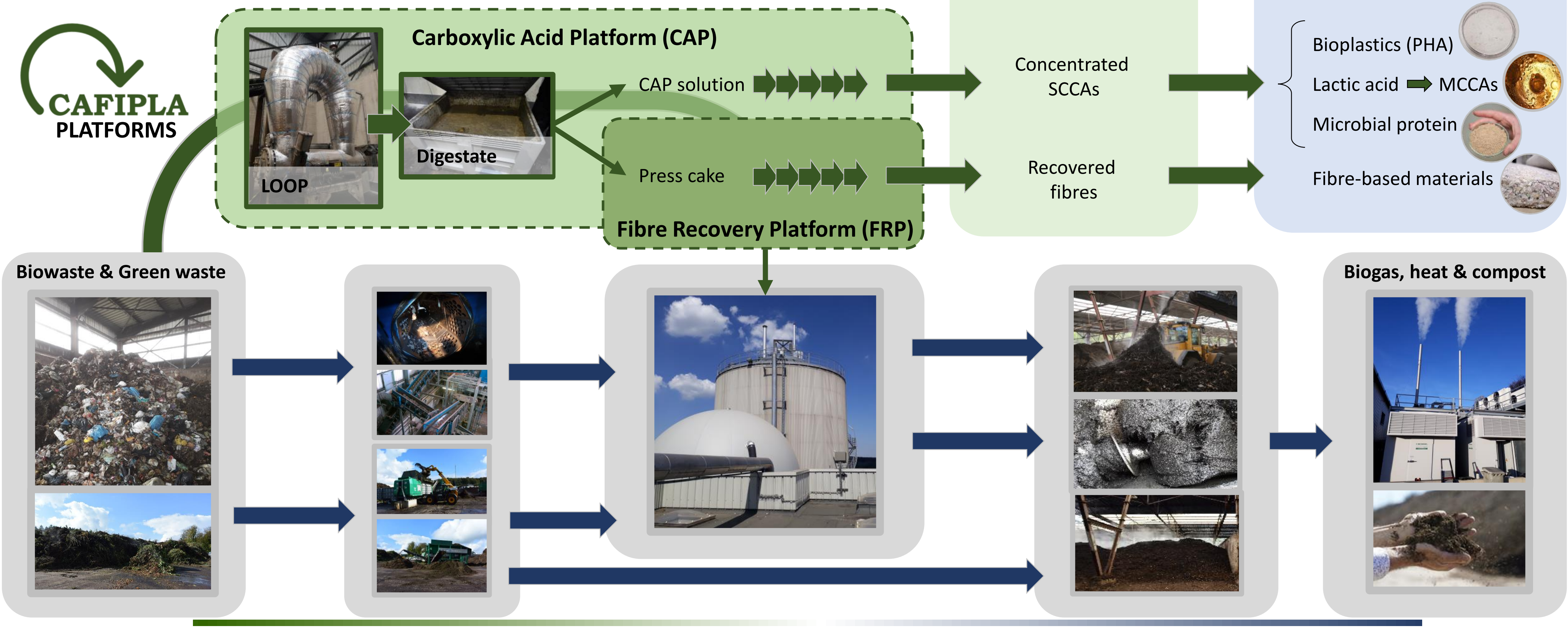
[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

Picture source: IDELUX

⇨ See SECTION 4

PILOT PLANT: INTEGRATION AT TENNEVILLE SITE

Derived from [2]

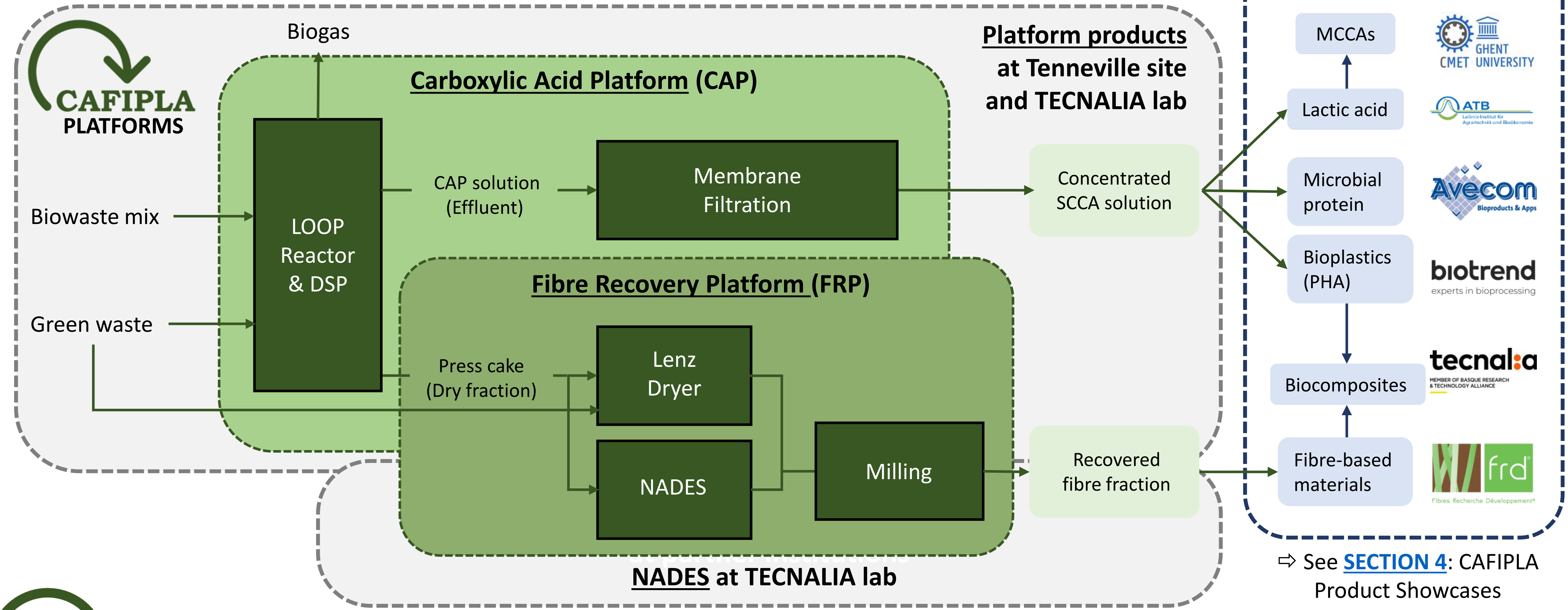


[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

Picture source: IDELUX

PILOT PLANT: PLATFORM AND END PRODUCT SYNTHESIS

Derived from [2]



⇨ See **SECTION 4**: CAFIPLA Product Showcases

[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

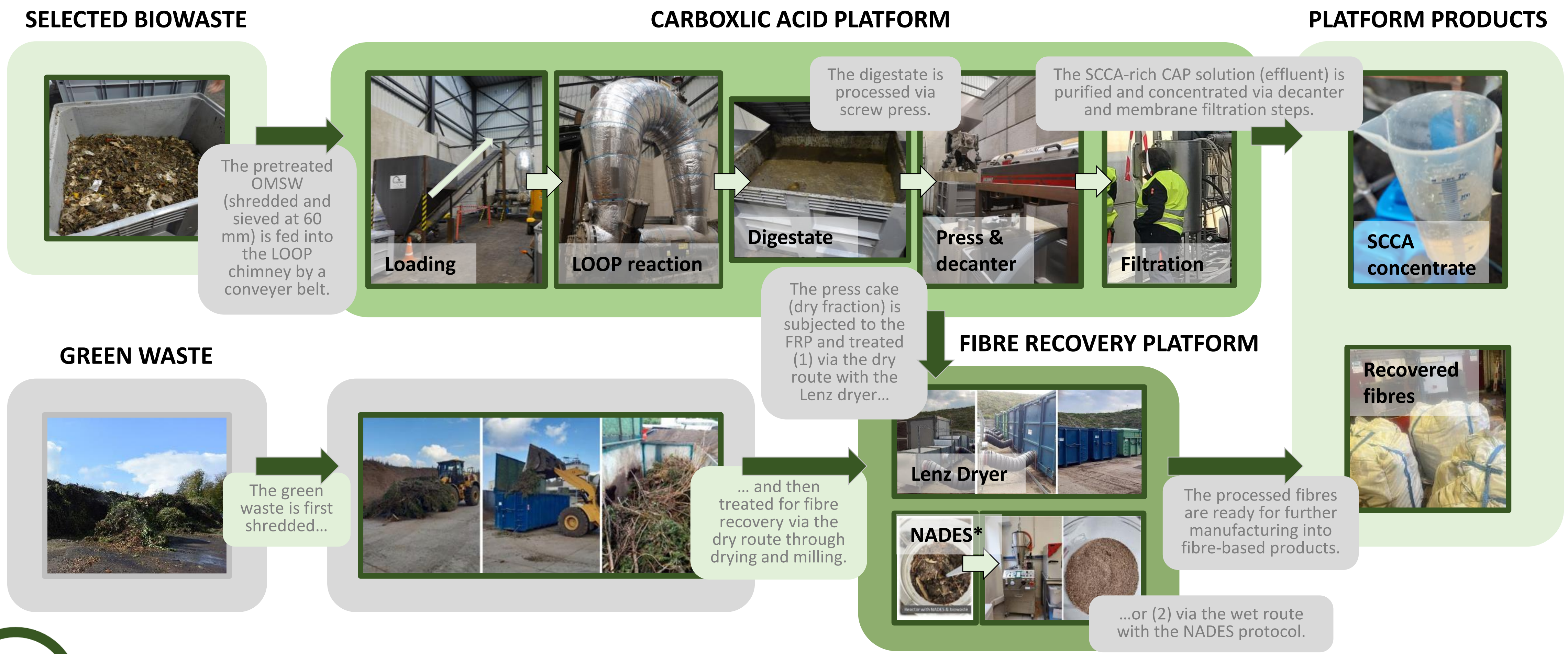
PILOT: THE CAFIPLA PILOT PLANT IN TENNEVILLE AT A GLANCE

1 Loading with biowaste
2 Transport to LOOP
3 Feeding LOOP chimney
4 Entering LOOP reactor
5 LOOP process
6 Transfer to screw press
7 Pressing
8 Decanting
9 Filtration

Picture source: IDELUX

BIOWASTE: TREATMENT PROCESS VIA CAFIPLA PLATFORMS/TECHNOLOGY

Derived from [2]



*Natural deep eutectic solvents

[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

Picture source: IDELUX

THE LOOP: A SUCCESSFUL DEMO CASE FOR THE CAFIPLA BIOWASTE VALORISATION PLATFORM

- CAFIPLA developed the **LOOP pilot plant** with two platforms for an optimised bioconversion of heterogenous biowaste, such as OMSW.
- Using a broad range of **feedstocks** and offering a **variety of products and applications** are key to fully exploit and valorise biowaste input streams.
- Sorting OMSW into easily or more slowly biodegradable fractions allows optimised conversion: E.g., food wastes rich in sugars and fat are processed via the **CAP to extract short chain carboxylic acids (SCCA) and nutrients** in solution, while green waste with high fibre contents is treated via the **FRP to recover insoluble fibres** from the remaining biomass fraction.
- **CAP research** optimises process control strategies to obtain specific spectra of short chain carboxylic acids to feed into bioproduction of microbial protein, PHA or medium chain carboxylic acid (MCCA)-biooil.
- **FRP optimisation** was done by fractionation into different fibre ranges resulting in intermediates that can be valorised as packaging material or insulation.
- **Benefits of the integrated CAFIPLA process:** (i) Improving the waste treatment process to reduce the costs, (ii) Making AD and composting of OMSW more profitable, (iii) Using the "carbon value" of OMSW thus promoting the circular economy.
- **The pilot** is designed to treat up to 10 tonnes of the separately collected biowaste at IDELUX per year reaching carboxylic acid and fibre yields of more than 80%. It is operated on working days (5/7 days) for the initial separation and FRP, and 7/7 days for the CAP. For the first half-year trial period, the CAFIPLA team aims at producing at least 250 kg of each – carboxylic acids and fibres.
- With a technology readiness level (TRL) 5, the pilot demonstrates the **upscaling potential of the CAFIPLA process**.

Derived from [2]

[2] Horizon 2020 Project (2020-2023) CAFIPLA – Deliverable D4.6 (2026) – Pilot plant integrated at IDE (Grant agreement ID: 887115). [Online]

CAFIPLA

SECTION 4

CAFIPLA Product Showcases

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PHA DERIVED FROM THE CAFIPLA PROCESS

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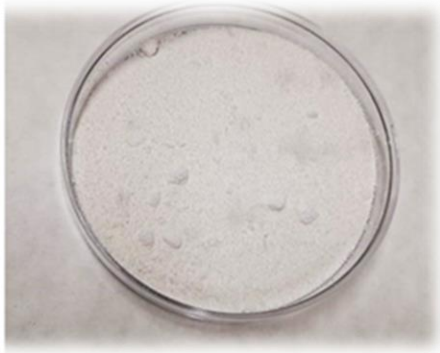
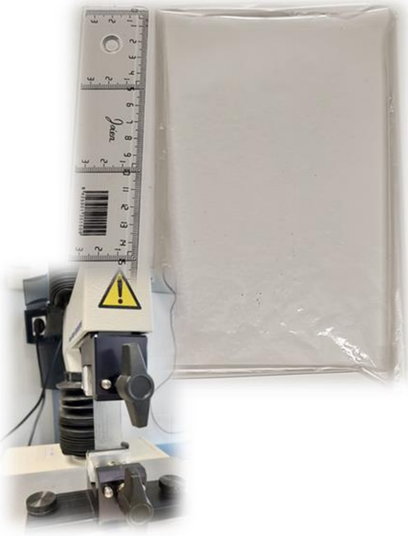
experts in bioprocessing
tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE


Crystalline PHA


PHA powder


PHA films obtained by casting


PHA films with high transparency

- PHA biopolymers can be obtained with 50-55% PHA content
- PHA can be produced as solid (powder, crystal) or as film
- PHA can be casted to obtain especially thin and transparent films e.g., for packaging applications
- Material properties of PHA biopolymers were characterized e.g., melting temperature, tensile strength, elongation at break, young modules

MARKET APPLICATIONS

- Biodegradable Biobased plastics
- Biocomposites

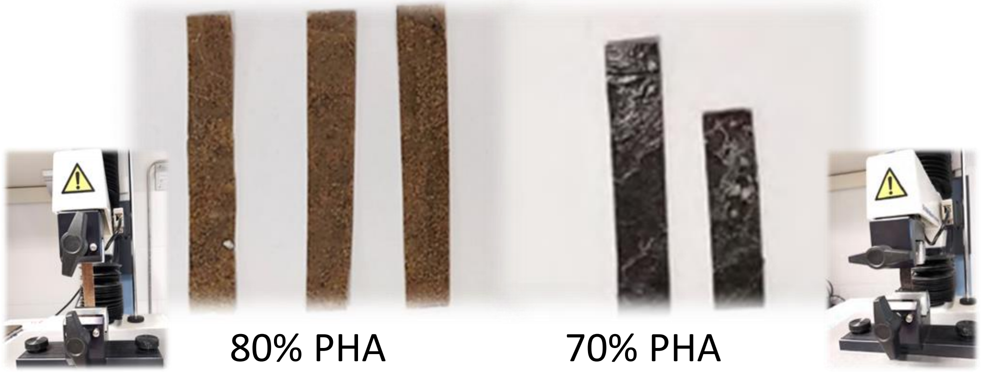
Picture source: TECNALIA

biotrend
experts in bioprocessing

tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

BIOCOMPOSITES DERIVED FROM THE CAFIPLA PROCESS

Biocomposite samples



80% PHA
10% Fibres

70% PHA
20% Fibres

- Biocomposites made from short fibres obtained from green waste and PHB
- Tailored properties by adaptation of fibre/PHB content
- Glycerol used as plasticiser

MARKET APPLICATIONS

- Domestic sector
- Building materials
- Automotive industry

INSULATION MATERIALS DERIVED FROM THE CAFIPLA PROCESS

Insulation materials

Insulation panel made with paper waste

Insulation panel made with green waste

- Insulation materials made with long fibres and other selected raw materials
- Material properties of insulation panels were characterized, e.g., density, thermal conductivity
- The thermal conductivity was found to be close to commercial products

MARKET APPLICATIONS

- Housing
- Indoor construction
- Outdoor construction

Picture source: FRD

FIBRE-BASED MORTARS DERIVED FROM THE CAFIPLA PROCESS

Fibres grinded for mortar production

Fibre-based mortar

- Mortar was made with short fibres and other selected raw materials
- Material properties of mortar was characterized, e.g., bending resistance, compression resistance and density
- The mechanical properties are equivalent to some commercial products

MARKET APPLICATIONS

- Mortars
- Cement
- Tile adhesive

Picture source: FRD

MICROBIAL PROTEINS DERIVED FROM THE CAFIPLA PROCESS

Liquid Microbial protein

Microbial protein paste

Microbial protein powder

- Short-chain carboxylic acids (SCCA)s from the Carboxylic Acid Platform (CAP) are converted into Microbial protein
- 3 step process from SCCA to microbial protein powder:
  - Fermentation of SCCAs into microbial protein
  - Dewatering of liquid microbial protein by centrifugation
  - Drying of microbial protein paste
- Microbial protein is obtained as powder with a high protein content (> 60% protein/TSS)

MARKET APPLICATIONS

- Food additive
- Feed additive
- Slow-release fertiliser

Picture source: Avecom

CAPROIC ACID & BIO OILS DERIVED FROM THE CAFIPLA PROCESS

GHENT UNIVERSITY CMET

ATB

Granular biomass

Product extraction

MCCA bio-oil

- Caproic acid is produced from lactic acid via a dedicated microbial chain elongation process
- Efficient and continuous production in an optimized bio-reactor configuration with selective in-situ product recovery
- High product selectivities of >90% for chain elongation intermediates

MARKET APPLICATIONS

- Bulk chemical
- Energy sector e.g., biofuel
- Bio-plasticizer
- Antimicrobial feed additive

CAFIPLA: IMPACT OF BIOWASTE-DERIVED MATERIALS IN AN EXPANDING BIOECONOMY

The present final report on the market assessment of CAP/FRP-based bioproducts and CAFIPLA as technology evaluates the CAFIPLA platform and products in the bigger picture of the **bioeconomy expansion.** Biomass represents an **essential resource for biomanufacturing** and demand as well as competition will increase accordingly in a growing bioeconomy.

Biowaste as abundant and currently underused feedstock will therefore play a key role in:

- creating novel urban **bioeconomic value chains,**
- **closing the loops** for various material streams,
- mitigating **climate change** by reducing emissions from landfills and
- increasing **independence from fossil raw materials**.

Exploiting this potential by developing the needed technologies to create biowaste-based production routes are consequently paramount to establish a **competitive European bioeconomy**.

CAFIPLA: IMPACT OF BIOWASTE-DERIVED MATERIALS IN AN EXPANDING BIOECONOMY

The CAFIPLA technology as **stand-alone biorefinery concept** turns heterogenous biowaste into valuable platform products and end products with high market potentials. Furthermore, the CAFIPLA platform offers an attractive **complementation for anaerobic digestion plants** by generating end products with 3 - 15 times higher value per ton of input material compared to conventional valorisation approaches. The CAFIPLA process additionally represents an economic alternative or **add-on for conventional sugar-based biorefineries** by extending the circular product portfolio while avoiding energy and chemical costs for sugar extraction.

With the **TRL 5 CAFIPLA pilot plant** - the “LOOP” - a successful demo case for the CAFIPLA biowaste valorisation concept was established at the organic waste treatment site of IDELUX in Belgium. The targeted treatment of easily biodegradable and recalcitrant fractions via the two CAFIPLA platforms, **CAP and FRP**, allows for an optimised conversion into the **platform products** carboxylic acids and recovered fibres. The pilot is designed to treat up to 10 tonnes of separately collected biowaste per year reaching carboxylic acid and fibre yields of more than 80% and demonstrates the **upscaling potential of the CAFIPLA process**.

The **CAFIPLA end products** PHA, biocomposites, insulation materials, fibre-based mortars, microbial protein as well as caproic acid & bio-oils target various attractive markets. The diverse applications in e.g., the bioplastics, construction and automotive industry, the food, feed and agricultural sector, the bulk chemical industry and the energy sector highlight the **relevance of biowaste-derived materials in an expanding bioeconomy**.

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