



Combining carboxylic acid production and fibre recovery as an innovative, cost-effective, and sustainable pre-treatment process for heterogeneous bio-waste



- Is your company looking for sustainable products or materials/chemicals for its processes?
- Are you a decision-maker representing a city/region and looking for valorisation opportunities for unexploited biogenic waste streams?
- Are you a biogas plant operator searching for alternative value chains?

Background

The Green Deal and the resulting regulations/legislations create challenges for European companies: They have to search for new (sustainable) raw materials/ drop-in chemicals and novel technologies, e.g., to reduce greenhouse gas emissions or to adapt process chains to fit a circular economy.

At the same time, there are lots of un(der)utilized biogenic waste streams in Europe. Bio-waste accounts for 30-40% (approx. 90 million tons) of the total amount of municipal solid waste. To achieve the EU target to recycle 65% of the municipal waste by 2035, it is essential to establish required processes as soon as possible. There are already several such approaches for converting biogenic residual and waste materials into higher-value chemicals, polymers, feed, or food.

One of the most promising approaches is the conversion of these – often very heterogeneous – organic residues and waste materials to valuable products using two separate steps: Initially, the organic material is separated into fibrous biomass and easily biodegradable biomass. The fibres obtained are further processed for material applications. The remaining biomass is fed to a coupled energetic and material usage via anaerobic digestion processes.

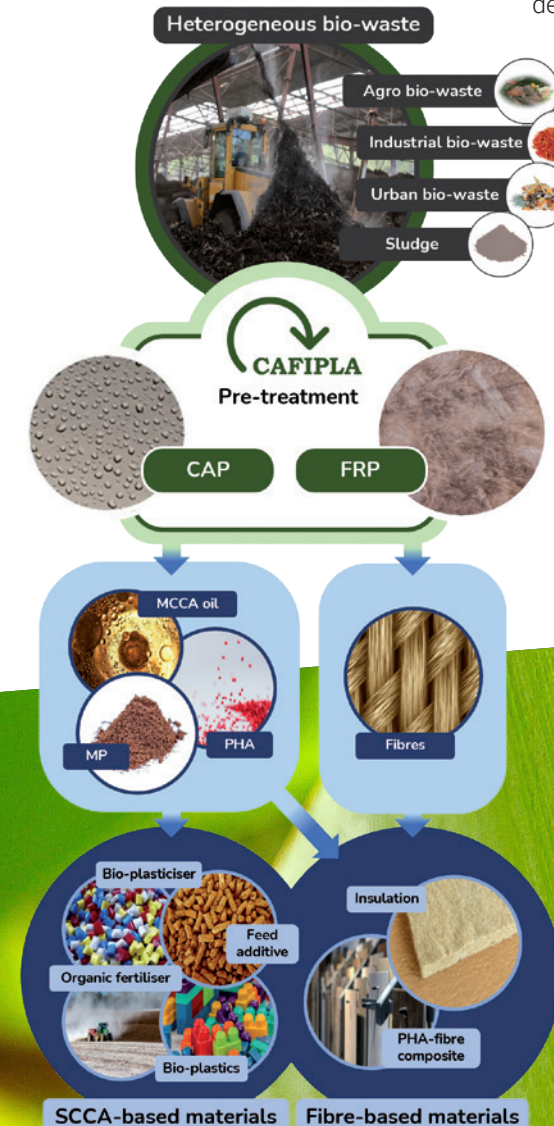
“The transition from simple sugars to organic wastes and residues for the production of chemicals and energy, is paramount in a circular bioeconomy”

José Pablo López Gómez, Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB)

CAFIPLA Project Overview

The CAFIPLA project started on June 1st, 2020 and is funded by the Bio-Based Industries Joint Undertaking (BBI JU) under the EU's Horizon 2020 research and innovation program.

Over a period of three years, CAFIPLA will develop a strategy for the valorisation of previously un(der)utilized biogenic residues and waste materials and contribute to the further elaboration of a competitive bioeconomy to achieve the Green Deal goals. The project will combine optimized mechanical and biochemical pre-treatment and separation steps, a Carboxylic Acid Platform (CAP) for carboxylic acid recovery and a Fibre Recovery Platform (FRP) into a single platform. The resulting intermediates will be converted into higher value compounds (chemicals, feed and biomaterials).



Schematic overview of the CAFIPLA process. CAP: Carboxylic Acid Platform; FRP: Fibre Recovery Platform; SCCA: Short chain carboxylic acids; MCCA: Medium chain carboxylic acids; MP: Microbial protein; PHA: Polyhydroxyalkanoic acid.

Carboxylic Acid Platform (CAP)

The technology for producing carboxylic acids is based on the well-known anaerobic digestion process. The process is steered towards carboxylic acids accumulation by carefully setting the physiochemical parameters within the reactor. A biochemical process, known as reverse β -oxidation or chain elongation, takes place and medium chain carboxylic acids like butyric-, valeric- and caproic acid are produced by the microbiome. In CAFIPLA, the carboxylic acid composition is controlled by optimized processes.

The process enables customers to upcycle organic waste streams and therefore contribute to a sustainable society. In addition, the technology produces carboxylic acids, as bio-based alternative for petrochemical products used in the chemical industry.

"As organic waste production continues to increase worldwide, of which only a fraction is currently valorised, the CAP offers a great opportunity to recycle organic material"

Jef Van de Poel, OWS Research Foundation



Continuous test set-up for upscaling carboxylic acid production in the lab.

Microbial Protein (MP)

MP has extraordinary properties as slow-release organic fertilizer. Depending on origin and quality of the carboxylic acids, nitrogen and phosphorous, MP can also be applied as high-value animal feed. Both the biofertilizer market and the global ingredients market are reported to have high growth potentials of more than 6% CAGR.

In CAFIPLA, protocols to produce MP from CAP-derived carboxylic acids (PROMIC) are developed based on a patented, aerobic process for upgrading under-valued streams.



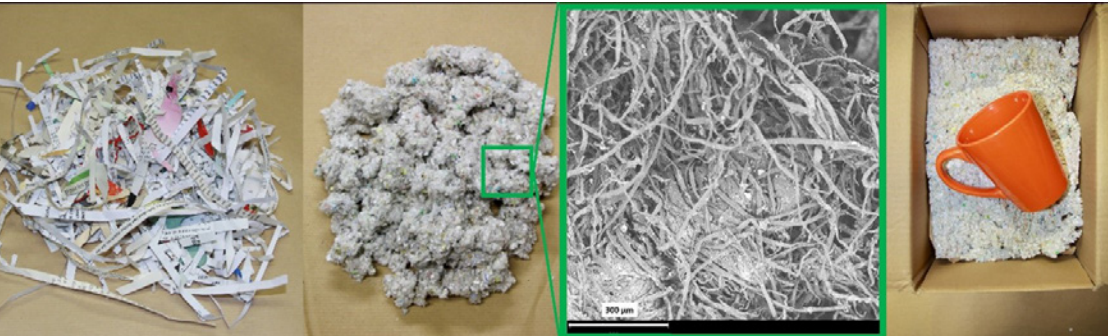
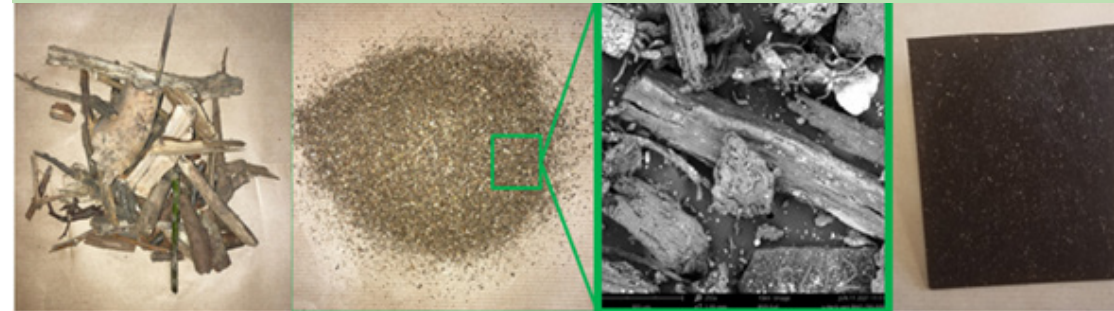
PROMIC production at pilot scale and PROMIC Single Cell Protein.

Fibre Recovery Platform (FRP)

The Fibre Recovery Platform (FRP) enables the environmentally friendly recovery of natural fibres from pre-treated biowaste mixtures by applying dry and wet extraction processes. The latter uses a technology based on deep eutectic solvents.

Unlike most biomass processing technologies that use high temperatures and pressures to remove lignin, the FRP process requires less energy and does not use toxic feedstocks and avoids the generation of hazardous wastewater streams. The technology developed in CAFIPLA enables the recovery of fibre fractions from biowaste. The platform thus provides access to previously underutilized, very cheap and locally available residual and waste materials with a limited carbon footprint.

Upcycling of green waste into filler material for biocomposites.



Upcycling of paper waste into material for shipping parcels.

Fibres

Significant growth is expected for both the composites market and the fibre insulation market in the coming years. The bio-composite market in particular is an attractive target market with a forecasted CAGR of >10% (2020 - 2027).

Fibres obtained from biogenic residual and waste materials via the FRP can either be converted into fibre-reinforced composites via optimized processes in combination with polyhydroxyalkanoates, also produced in CAFIPLA, or applied as insulation material.

Polyhydroxyalkanoates (PHA)

The biotechnological production of this biodegradable polymer holds immense potential, as PHA properties can be tailored by controlling the applied carbon source and fermentation strategy. Different monomer compositions and polymer sizes determine the mechanical properties of the polymer and thus, its use for various applications, from food packaging to agricultural mulch films. PHA is currently considered to have a tremendous growth potential of about 11% (CAGR; by 2024).

In CAFIPLA, optimized fermentation strategies for converting the carboxylic acids from CAP are applied to produce polyhydroxyalkanoates and optimized downstream processing protocols are developed.



Left: 50L and 250 L Pilot scale fermenters for the production of PHA.

Below: PHA film and Prototypes produced with the incorporation of PHA.



Lactic Acid (LA)

LA is a versatile organic acid that can act as the precursor for various other molecules. Due to its versatile applications in the biobased industry, LA is one of the 'Top Value-Added Chemicals from Biomass' of the US Department of Energy and one of UK's Top 10 Green Chemicals. Projections have estimated that the market value of LA will rise from \$2.64 billion in 2018 to over \$9 billion by 2025.

In CAFIPLA, LA is obtained from waste and residue streams, such as the organic fraction of municipal solid waste (OFMSW) using optimized fermentation and downstream processing approaches.



Above: Biowastes studied for the production of lactic acid.

Right: (Poly)Lactic acid produced from biowaste feedstocks.



Medium Chain Carboxylic Acids (MCCA)

MCCA rich bio-oil can, for example, be valorised as an antimicrobial feed additive, aiding in the feed sector with its efforts to decrease the use of antibiotics. Furthermore, MCCA can be used as bio-based chemicals with applications as a precursor for (drop-in) biofuels and bio-plasticizers in bioplastics, or flavourants in the food industry. Carboxylic acids are currently considered to have a high growth potential of approx. 5% (CAGR; 2020-2025).

A bio-oil composed of medium-chain carboxylic acids is produced within the CAFIPLA project by microbial fermentation of lactic acid.

Avecom NV



Classification: SME
Founding year: 1995
Country: Belgium

- **Expertise:** Avecom (Ghent) is an innovative SME specialized in steering and optimizing microbial processes and the engineering of microbiomes. We commercialize products and deliver expert services in the field of environmental biotechnology. Our innovations are applied in wastewater treatment, soil remediation and biodegradation, air management and sustainable feed and food ingredients. Apart from our own products, Avecom works in close collaboration with industrial companies for the research, development and upscaling of their new products and processes.

We have fully equipped laboratories and certified production facilities which allow to perform R&D starting from preliminary lab testing to proven pilot scale applicability. Furthermore, our team of experts is capable to identify bacterial species using the classic methods as well as through high throughput sequence techniques such as amplicon sequencing.

- **Main role in project:** Production of microbial protein (MP) from short chain carboxylic acids (SCCA) in the fermentation broth and recovery of MP as dry powder.

Avecom develops microbial fermentation processes in their own labs.



Website: www.avecom.be

Biopract GmbH



Classification: Industry R&D/Analytics/Services
Founding year: 1992
Country: Germany

- **Expertise:** At Biopract GmbH, our expertise comprises enzymes for biomass splitting and anaerobic fermentation, research, analysis, development and formulation of enzymes for agricultural and industrial applications as well as the development of application tests. We develop enzyme products to improve fluidity, productivity and performance in biogas fermentation production. We perform application studies on the efficacy of enzymes in industrial processes involving biomass. We are experts in analyzing the activity of added enzymes in animal feed and further complex matrices.
- **Main role in project:** Selection of enzymatic preparations for the specific substrates and purposes of the project and supply of samples for testing at lab and pilot scale.

Website: www.biopract.de/en

Biotrend – Inovação e Engenharia em Biotecnologia, S.A.



Classification: SME
Founding year: 2000
Country: Portugal

- **Expertise:** BIOTREND SA is a research-based company specialized in the development, optimisation and scale-up of bioprocesses, from 1 mL to 250 L scale. A network of partners with demonstration and relevant industrial scale facilities also guarantees the technology transfer of processes developed at Biotrend. Our advanced services help designing cost-competitive processes that are robust at industrially relevant scales, particularly in the area of industrial and marine biotechnology. We are experienced in dealing with a great variety of natural or genetically modified microorganisms to produce a wide range of products, from biomass to chemicals, biopolymers or recombinant enzymes.
- **Main role in project:** Assessment of the application potential of carboxylic acids from the carboxylic acid platform (CAP) as main raw material for biopolyesters as well as PHA recovery.

Small scale fermentation process at the Biotrend lab.



"The transition from a fossil fuel-based economy to a biotechnology-based economy, in which biobased and biodegradable plastics are produced, is one essential step to guarantee the planet sustainability"

Ana Carolas, Biotrend – Inovação e Engenharia em Biotecnologia, S.A.

Website: www.biotrend.pt

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH



Classification: Research
Founding year: 2008
Country: Germany

- **Expertise:** DBFZ works as a central and independent thinker in the field of energy and material use of biomass. It addresses the question of how the limited biomass resources available can contribute to a sustainable and efficient bioeconomy. DBFZ's mission embraces technical, ecological, economic, social policy and energy business issues throughout the supply chain. DBFZ drives and supports the development of new processes, methodologies, and concepts in close cooperation with industrial partners.
- **Main role in project:** Biomass potential and biomass availability analyses, assessment of market players and biomass supply chains.



Website: www.dbfz.de

DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.



Classification: RTD
Founding year: 1926
Country: Germany

- **Expertise:** DECHEMA has many years of experience in the technical, economic, and environmental assessment of novel technologies and processes. It provides consulting, independent analyses and scouting services to start ups, established companies and investors. For its clients, it evaluates trends, new technologies and identifies R&D needs in its core sectors „Bioeconomy and Biotechnology“, „Chemical Production“, „Raw Materials“, „Energy & Climate“ and „Industrial Water Management“. Furthermore, it has been developing successful roadmaps for national and international associations, organizations, and ministries for many years.
- **Main role in project:** Execution of market analyses, participation in Life Cycle Assessment (LCA) and coordinating marketing, dissemination, and communication activities.



DECHEMA
main building
in Frankfurt.

Website: www.dechema.de/en

Fibres Recherche Développement (FRD)



Fibres Recherche Développement®

Classification: SME
Founding year: 2008
Country: France

- **Expertise:** FRD is a private innovation company that promotes the emergence and development of innovative applications for biomass-derived plant fibres. FRD has expertise in the full range of plant-fibre extraction, characterisation and quality management to applicative implementation activities, from the plant all the way to end applications (insulation materials, concrete, panels, plasturgy & composite and cosmetics). FRD works with all types of biomasses to optimize their fibre fraction. This includes dedicated crops like fibre flax, hemp and miscanthus, agricultural coproducts like cereal straw and oilseed, viticultural coproducts like vine stocks and shoots, or food processing coproducts like sunflower seed hulls.
- **Main role in project:** Fibre extraction and characterisation, assessment of the application potential of fibre fractions from the fibre recovery platform (FRP) as main raw material for biobased materials (insulation material and biocomposites).

*"The future of low-carbon footprint materials
will be based on bio-based materials and
the use of recycled matter"*

Laurent Bleuze, Fibres Recherche Développement

Website: www.f-r-d.eu

Fundación TECNALIA Research & Innovation



Classification: RTD
Founding year: 1998
Country: Spain

- **Expertise:** TECNALIA is the largest centre of applied research and technological development in Spain, a benchmark in Europe and a member of the Basque Research and Technology Alliance. We collaborate with companies and institutions to improve their competitiveness, people's quality of life and achieve sustainable growth. We do it thanks to people who are passionate about technology and committed to building a better society. Key features that turn TECNALIA into a powerful agent in co-operative endeavours are its private nature; the focus on applied research; the fact of being a centre of international excellence; the impact on local industry and its openness to other organizations or networks keen to interact and co-generate knowledge.
- **Main role in project:** Coordination of the CAFIPLA project and activities regarding sustainability assessment as well as fibre extraction, protein and PHB characterisation.

IDELUX Environnement



Classification: Intermunicipal
Founding year: 1974
Country: Belgium

- **Expertise:** Waste management is a challenge and an essential public service mission. At IDELUX Environnement, we want to accomplish this task by meeting our citizen's expectations and respecting the environment in the best possible way. IDELUX Environnement is managing the municipal waste of 55 municipalities (44 municipalities from the province of Luxembourg and 11 municipalities from the province of Liège, for a total of 376 720 inhabitant-equivalents) from their collection to their valuation. Organic municipal waste recovery has always been a priority for IDELUX Environnement. The separate door to door collection of municipal organic waste has been organized since 2005 and its valorisation through anaerobic digestion since 2008.
- **Main role in project:** Providing the study case plant for proof of concept to combine carboxylic acid production and the fibre recovery pre-treatment process: industrialisation of the pre-treatment platform design by implementation of a pilot (TRL5) in our organic waste treatment plant.

Waste recovery
site in TENNEVILLE.



Leibniz Institute for Agricultural Engineering and Bioeconomy e.V. (ATB)



Classification: Public Research Institute
Founding year: 1992*
Country: Germany

- **Expertise:** The Leibniz Institute for Agricultural Engineering and Bioeconomy is a pioneer and a driver of bioeconomy research.

We create the scientific foundation to transform agricultural, food, industrial and energy systems into a comprehensive bio-based circular economy.

We develop and integrate techniques, processes and management strategies, effectively converging technologies to intelligently crosslink highly diverse bioeconomic production systems and to control them in a knowledge-based, adaptive, and largely automated manner. We conduct research in dialogue with society - knowledge-motivated and application-inspired. The Bioconversion working group deals with the production, through fermentations, of various basic and special chemicals from biogenic raw materials or residues.

- **Main role in project:** Production of lactic acid from organic wastes employing fermentations.



Biowaste substrates and pilot scale Electro dialysis equipment for lactic acid recovery.

Website: www.atb-potsdam.de/en

OWS Research foundation (OWS RF)



Classification: SME (research/engineering/environmental services)
Founding year: 2021
Country: Belgium

- **Expertise:** OWS RF is a small research and development institution with strong connections to Dranco NV and Organic Waste Systems. Dranco NV has developed innovative and patented designs for biogas plants with more than 30 years of experience in the field. OWS offers services in biodegradability, compostability and ecotoxicity testing, auditing, controlling, and sorting of different waste streams and performs LCA studies.
- **Main role in project:** Optimization of the carboxylic acid platform (CAP) and participation in the validation of the CAFIPLA techniques at pilot scale.



Lab-scale batch test for carboxylic acid production.

Website: www.ows.be

Universität für Bodenkultur Wien (BOKU)



Classification: RTD
Founding year: 1872
Country: Austria

- **Expertise:** BOKU is an education and research institution for renewable resources. The university responds to central societal challenges with its focus on problem-solving rather than a discipline-oriented structure, combining expertise in the fields of natural sciences, engineering as well as social and economic sciences. Looking back on a long and successful history in inter- and transdisciplinary research and teaching, BOKU provides competent answers to the scientific community, policy makers and partners in society and economy on topics such as climate change, advancement of sustainable agriculture and forestry, bioeconomy, environmental protection, sustainable energy security, food safety and security, and securing and promoting the quality of life in urban and rural living spaces.
- **Main role in project:** Characterization of organic waste materials and development and optimization of combined mechanical and biochemical pre-treatment of organic waste streams to produce input streams for fermentation process and fibre applications.

Website: www.boku.ac.at/ifa-tulln

Universiteit Gent (UGent)



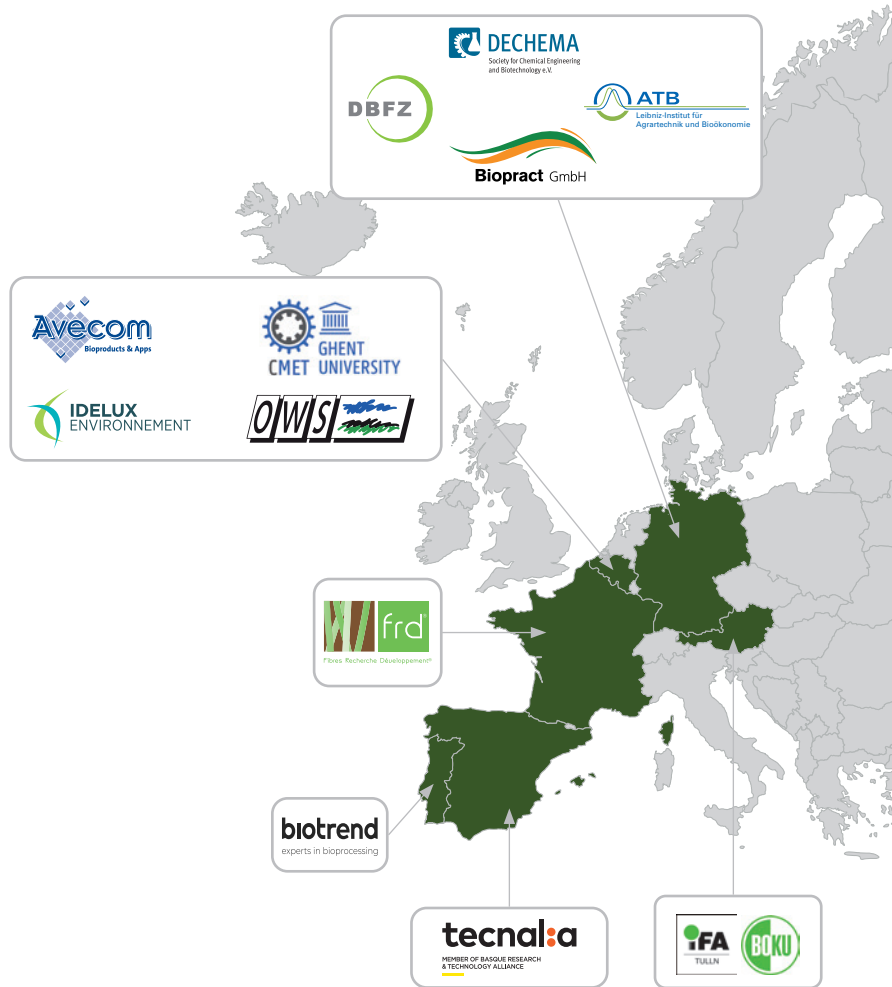
Classification: RTD
Founding year: 1817
Country: Belgium

- **Expertise:** Ghent University with its 11 faculties is an open, pluralistic, and comprehensive university. Within UGent, the Center for Microbial Ecology and Technology (CMET) is specialized in the study and application of mixed microbial communities. The research domains are (1) Applied Microbial Ecology, (2) Host-Microbiome Interaction Technology, (3) Life Support systems for Space, (4) Microbial Electrocatalysis and Electrochemical engineering, (5) Resource Recovery and Valorisation and (6) Water Treatment and Production. As such, research activities are very diverse, yet all with the same goal of better understanding and steering ecological processes with an ultimate aim of improving and enabling biotechnological applications. The CAFIPLA project fits within CMET's research domains Applied Microbial Ecology and Resource Recovery.
- **Main role in project:** Characterization, monitoring and steering microbial communities for optimized conversion or production as well as investigating the application potential by converting lactic acid into caproic acid.

"Unlocking organic waste's full potential will eliminate our dependency on fossil resources"
 Kevin Sabbe, Universiteit Gent

Website: www.cmet.ugent.be

Consortium



CONTACT

Project Coordination

TECNALIA

Thomas Dietrich

Phone: +34 664 039 292

E-mail: thomas.dietrich@tecnalia.com

Website: www.tecnalia.com



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 Bio based Industries
Consortium

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