CAFIPLA

D1.1 REPORT ON THE INITIAL MARKET ASSESSMENT OF CAFIPLA AS BIO-WASTE VALORISATION STRATEGY AND PRE-TREATMENT TO FEED THE BIO-ECONOMY WITH CAP/FRP BASED BIOPRODUCTS

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This project has received funding 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".

Bio-based Industries Consortium

Horizon 2020 European Union Funding for Research & Innovation

BBI JU

COLOPHON

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
D1.1 Report on the initial market asessment of CAFIPLA as bio-waste valorisation strategy and pre-treatment to feed the bioeconomy with CAP/FRP based bio-products	
Start of the project	01.06.2021
Duration time	36 months
Delivery date	28th February 2021
Responsible for this deliverable	DECHEMA e.V.
Dissemination level	Public

This project has received funding 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".

DISCLAIMER

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.

It must be stressed that the views expressed in this 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 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 D1.1 (2021), 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:
CAFIPLA – D1.1 (2021), 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.

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SUMMARY

The deliverable *D.1.1. Report on the initial market assessment of CAFIPLA as bio-waste valorisation strategy and pre-treatment to feed the bio-economy with CAP/FRP based bioproducts* gives a first overview on the market demand for the CAFIPLA targeted products, namely PHA, Caproic acid as a main representative for medium chain carboxylic acids (MCCA), Microbial protein (MP) and fibres.

By analysing relevant literature studies, market reports and databases for each of the products an initial assessment on product specifications, value chains, main applications, targeted markets and market potentials is given. Challenges and opportunities regarding techno-economic, environmental and legislative aspects are evaluated and highlighted. Furthermore, hurdles of each products and the provided CAFIPLA solutions are presented.

CAFIPLA technologies represent an attractive utilization option for bio-waste, 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. On the one hand, the market attractiveness of the products developed within the project will also benefit from the changing framework conditions (e.g. increased awareness of environmental and health issues, legal framework, etc.). On the other hand, the products tailored within the project target markets that 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.

TABLE OF CONTENT

ABBREVIATION

	Description
TEC	Fundación Tecnalia Research & Innovation
DBFZ	Deutsches Biomasseforschungszentrum Gemeinnutzige GmbH
IDE	Idelux Environnement
BPG	Biopract GmbH
BOKU	Universiät für Bodenkultur Wien
FRD	Fibres Recherche Développement
OWS	Organic Waste Systems NV
ATB	Leibniz Institut für Agrartechnik und Bioökonomie e.V.
UGH	Universiteit Gent
BIO	Biotrend - Inovação e Engenharia em Biotecnologia, S.A.”
AVE	Avecom
DEC	DECHEMA Gesellschaft für chemische Technik und Biotechnologie e.V.

	Description
DM	Dry mass
MCCA	Medium-chain carboxylic acids
MP	Microbial protein
NFC	Natural fibre composite
N	Nitrogen
P	Phosphate
PE	Polyethylene
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybenzoate
PHBV	Polyhydroxybutyrate-Co-Valorate
PHV	Polyhydroxybutyrate
PP	Polypropylene
SCCA	Short-chain carboxylic acids
SCP	Single-cell proteins
WPC	Wood plastic composite

INTRODUCTION

The 3-year CAFIPLA project will radically alter the biomass pre-treatment approach for bio-economy applications. Current biomass use comes at a high cost, either in terms of land use (sugar/starch crops) or energy and chemical use. On the other hand, bio-waste is massively produced in urban or rural context but almost not valorised or solely in low-value applications (*inter alia* due to its heterogenous nature).

CAFIPLA tackles both issues by developing an integrated biomass valorisation strategy that combines the carboxylic acid and fibre recovery platform (CAP/FRP). CAFIPLA firstly optimises the separation of the easily biodegradable fraction and recalcitrant biomass, as input for the CAP and FRP, respectively. This allows the implementation of tailored valorisation strategies for both routes, which in turn allows the use of heterogeneous bio-waste as input, while still ensuring high overall yields. In the CAP, research will focus on process control strategies to obtain specific spectra of carboxylic acids to feed into bioproduction of microbial protein, PHA or caproic acid biooil. In the FRP, fractionation into different fibre ranges will result in intermediates that can be valorised as packaging material or insulation. A TRL5 pilot will demonstrate the CAFIPLA upscaling potential.

GOAL AND AIM OF THE MARKET ANALYSIS

CAFIPLA develops a radically new approach to biomass use and pre-treatment for the creation of **4 new bio-economy value chains.** CAFIPLA will establish **two platforms** to achieve maximal valorisation of currently underused biomass streams, into **4 bioproducts.**

The following report on the initial market assessment gives a first overview on the CAFIPLA targeted products and analyses their market demand, price developments as well as technological and regulatory barriers and opportunities.

CAFIPLA 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

OVERVIEW

- family of polyesters that are biobased, biosynthesized, biocompatible, and biodegradable [P1]
- > 150 different PHA monomers identified
- short-chain-length PHAs (scl-PHAs) consist of 3 - 5, medium-chain-length PHAs (mcl-PHAs) of 6 - 14 carbon atoms* [P1]
- scl-PHA Poly(3-hydroxybutyrate) (PHB), most widespread and best characterized member of PHAs, is a homopolymer of 3-hydroxybutyrate [P8]

OVERVIEW - MARKET

- PHAs showed fastest growing rate within the group of bio-based polymers within the next years [P7]
- PHAs are expected to increasingly substitute conventional plastics with similar physicochemical, thermal, and mechanical properties (e. g. polypropylene, low-density polyethylene) [P2]

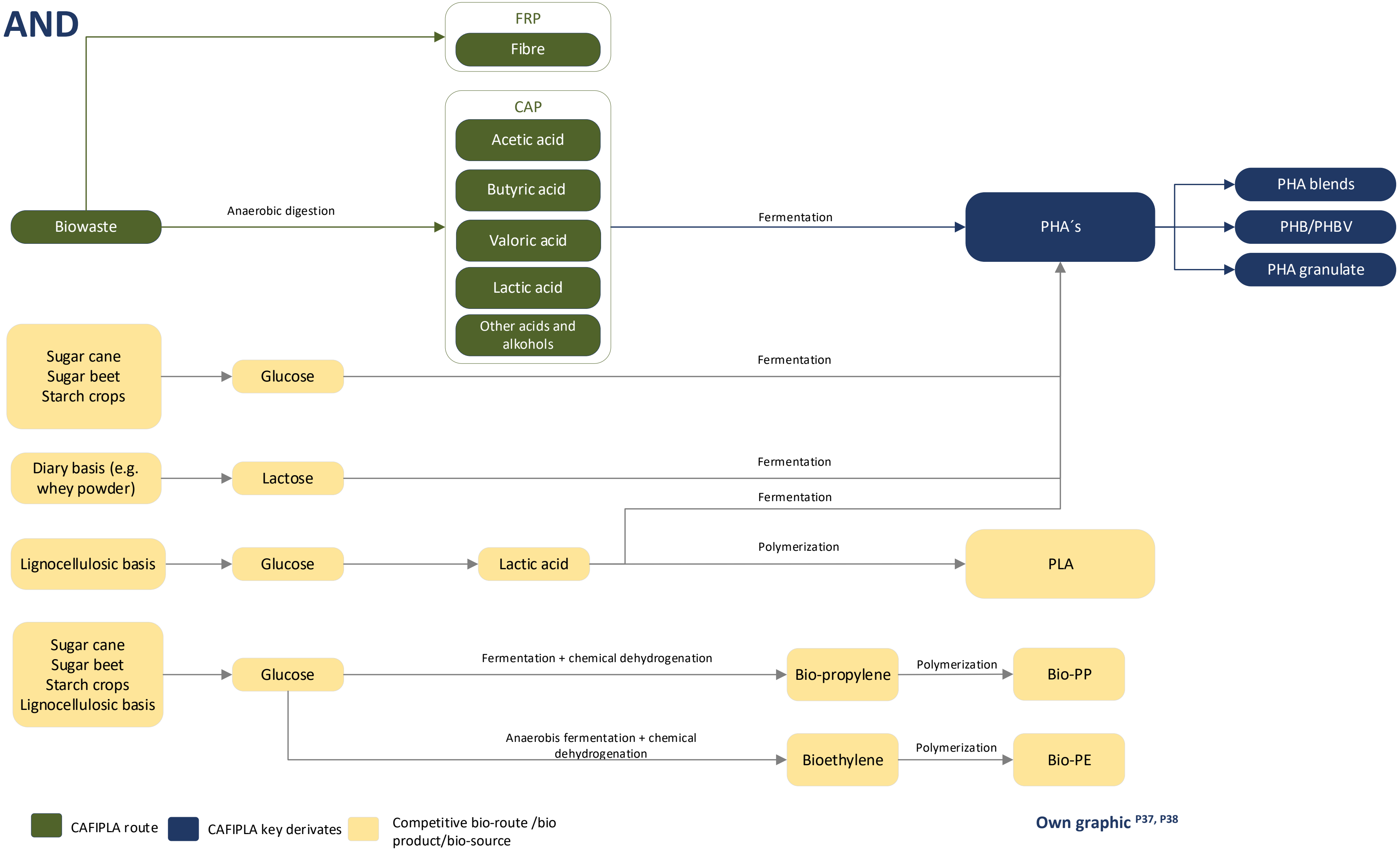
* number of carbon atoms refers to the repeating monomer

OVERVIEW – PRODUCTION AND APPLICATION

- commercial production mainly via fermentation processes applying sugars or plant oils; bioprocessing of waste streams gains increasing importance [P1]
- raw material costs currently account for around 40 - 50 % of total production costs [P14]
- scl-PHAs mainly utilized for production of disposables and packaging material; mcl-PHAs used for higher value-added application (such as medical applications); mcl-PHAs have elastomeric properties [P2]
- especially pure PHB only shows limited applicability primarily because of its brittleness and limited processing window [P8]. To improve quality
    - I. PHAs can be blended with other polymers
    - II. composites can be produced with compatible materials
    - III. the structure of polymers can be altered via feeding strategy during bioprocess
    - IV. addition of processing aids to the masterbatch mix such as plasticisers[P1,P2,P8]

PRODUCTION PROCESSES AND COMPETITIVE ROUTES

- At current low prices per barrel of crude oil, PHAs will also compete with bio-based polymers with similar physicochemical, thermal, and mechanical properties.
- Competition with biobased polypropylene and biobased low-density polyethylene therefore is conceivable.
- Bio-PP and bio-PE, however, have the major disadvantage over PHAs in that they are not biodegradable.
- PLA as the most widely produced biopolymer.



Own graphic P37, P38

PHA MANUFACTURERS (PILOT AND INDUSTRIAL SCALE)

Producer	Link	Country	Substrate	Product/Trademark	Production capacity [t/a]
Biocycle PHB Industrial	http://www.biocycle.com.br	Brazil	Cane sugar (Saccharose)	PHB, PHBV (BIOCYCLE)	3,000
Biomer	https://www.biomer.de/	Germany	Sugar (Sucrose)	PHB pellets (Biomer)	n.a.
BluePHA	http://en.bluepha.com/	China		Customized PHBVHHx, PHV, P3HP3HB, P3HP4HB, P3HP, P4HB synthesis	1000
Danimer Scientific	https://danimerscientific.com/	USA	Cold pressed canola oil	mcl-PHA (Nodax PHA)	13,600
Kaneka Corporation	https://www.kaneka.co.jp/en/	Japan	Plant oils	PHB-PHHx (AONILEX)	3,500
Mango Materials		USA	Methane	PHB (YOPP PHA)	> 1
Nafigate (Hydal) /BOCHEM	https://www.nafigate.com	Czech Rep	Waste oil	PHB	n.a.
Newlight Technologies	https://www.newlight.com/	USA	Oxygen from air and carbon from captured methane emissions	PHA resins (AirCarbon)	23,000
PolyFerm	https://www.polyfermcanada.com/	Canada	Sugars, vegetable oils	mcl-PHA (VersaMer PHA)	< 10

Based on references [P2,P3,P4,P5]; supplemented with own research

PHA MANUFACTURERS (PILOT AND INDUSTRIAL SCALE; CONTINUATION)

Producer	Link	Country	Substrate	Product/Trademark	Production capacity [t/a]
RWDC Industries	https://www.rwdc-industries.com/	Singapore	Waste cooking oil	mcl-PHA→PHBH compounds & composites	5,000
Shenzhen Ecomann Biotechnology	http://ecomann.sx-gear.com/	China	Sugar or glucose	PHA pellets, resins, microbeads (AmBio)	5,000
SIRIM Bioplastics Pilot Plant	https://www.sirim.my	Malaysia	Palm oil mill effluent (POME), crude palm kernel oil	Various types of PHA	2,000
Tepha	https://www.tepha.com/	USA	Sugars, 4HB precursors	P4HB,P(3HB-co-4HB) (TephaFLEX)	< 10
TianAn Biologic Materials	http://www.tianan-enmat.com/	China	Dextrose deriving from corn	PHB, PHBV (ENMAT)	10,000 - 50,000
Tianjin GreenBio Material	http://www.tjgreenbio.com/en/	China	Sugar (Sucrose)	P(3,4HB) films,pellets/foam pellets (Sogreen)	10,000

Based on references [P2,P3,P4,P5]; supplemented with own research

MARKET DESCRIPTION BIO-BASED POLYMERS

- **Production volume polymers*** [P25] [million tons]**

  Bio-based: 38.8

  Total polymers: ~ 502

- **Global market volume 2020 [P28, P30] [billion €]**

  Bio-based polymers: ~ 9

  Total polymers: ~ 552

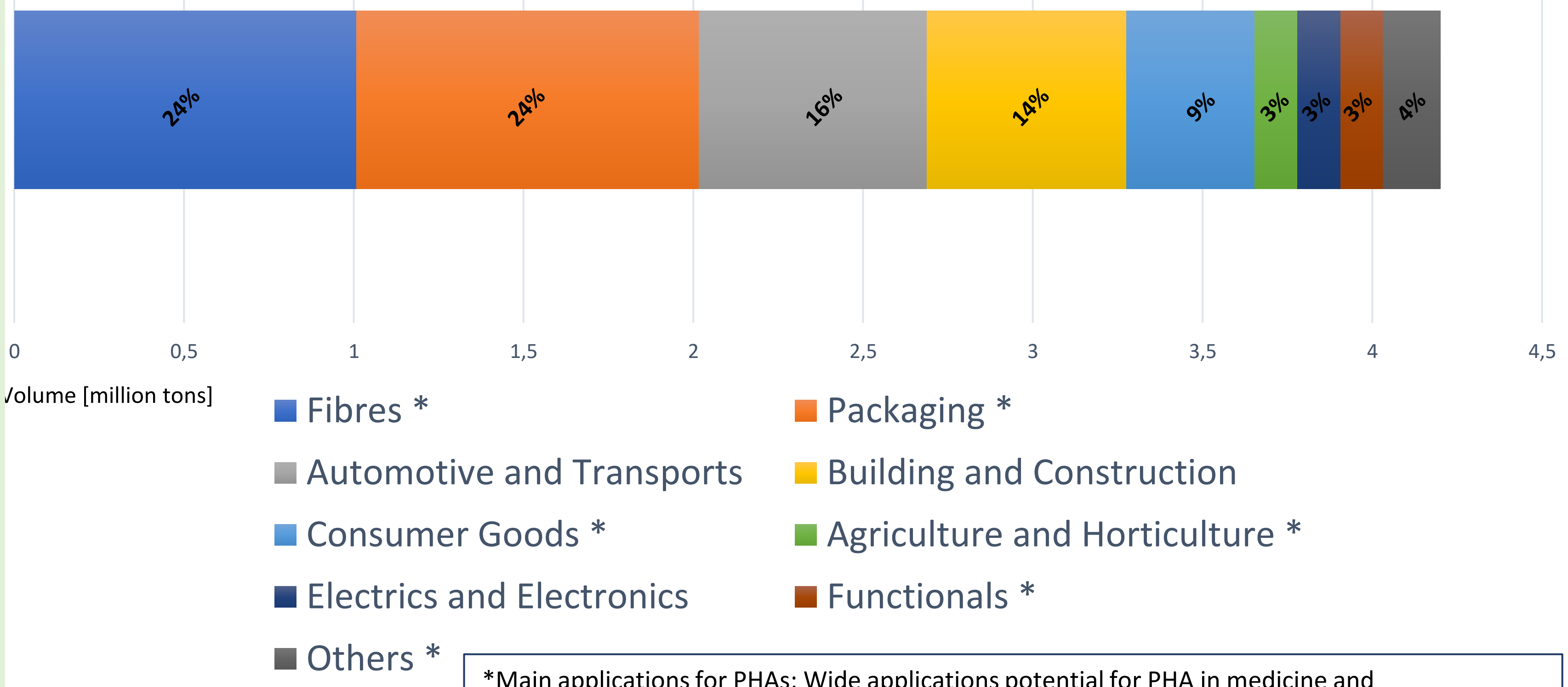
- **CAGR (2020 - 2025) [P26, P28, P29, P30, P31]**

  Bio-based polymers: >6

  Total polymers: 4 - 6

*** Includes functional and structural polymers, rubber and man-made fibers

MARKET SEGMENTS BIO-BASED STRUCTURAL POLYMERS (2020)** modified according to P25



*Main applications for PHAs; Wide applications potential for PHA in medicine and pharmaceuticals (e. g. biocontrol agents, drug carriers, implants, tissue engineering, anti- cancer agents) [P27] - biomedical market for PHAs currently still small.
** Bio-based structural polymers represent about 1% (4.2 million tons) of the total volume of structural polymers produced (about 370 million tons).

MARKET DESCRIPTION - PHA

Global PHA market [P9, P10] **[million €]**

2019: 47.07

2024: 80.93

Compound Annual Growth Rate

11.2% (Period 2020-2024)

PHA market price [P11, P12, P13, P14] **[€/ton]**

4.000 – 5.000

PP and PE market price [P13,P15,P16,P17,P18,P39]

LDPE: 1.20 – 1.45

HDPE: 1.00 – 1.50

PP: 1 – 1.20

Bio-PP: 1.80 – 2.40

Bio-PE: 1.20 – 2.1

PLA: 1.100 - 1.300

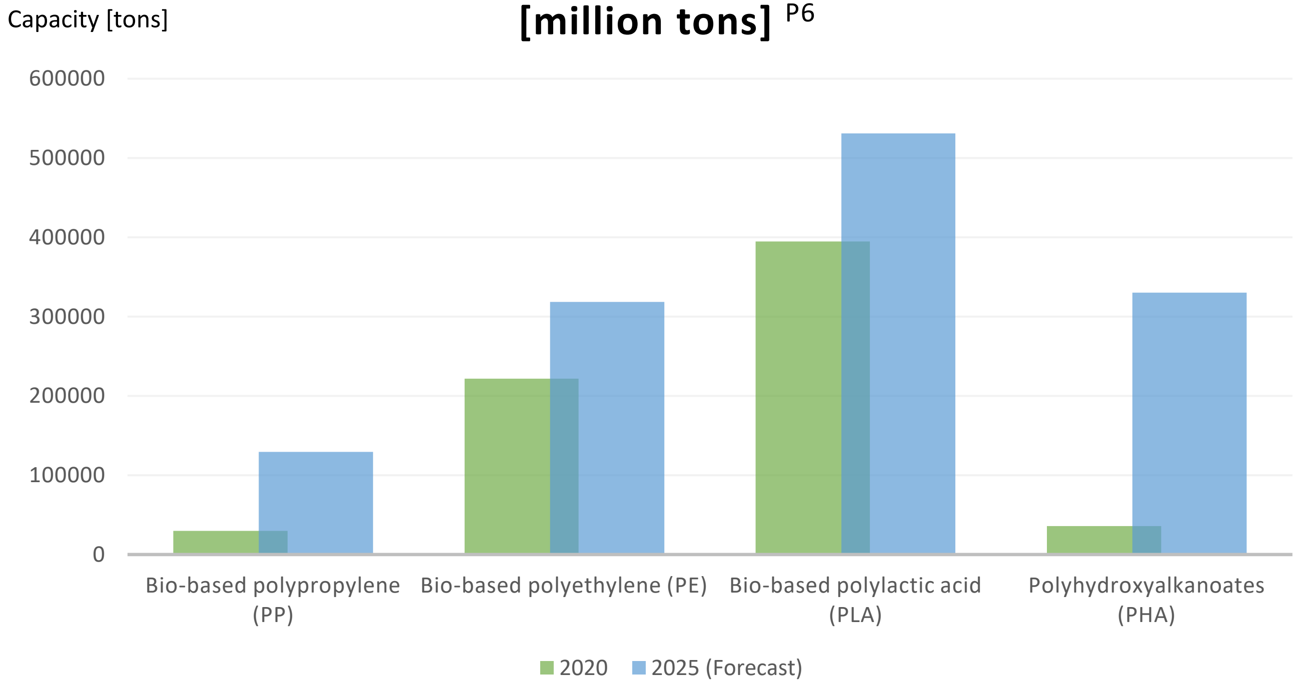
HDPE: High-density polyethylene;
LDPE: Low-density polyethylene

Global production capacities of bioplastics [P6]

2020: 2.11 million tons

2025: 2.87 million tons

Global production capacities of PP, PE, PLA, PHA [million tons] [P6]



2.1 PHA

Opportunities	Challenges
Techno-economic aspects see e. g. P20, P21, P22, P23, P24	
• Many potential markets; especially due to PHA's biodegradability	• Competition with conventional and well-established polymers
• Expected growth rate for bio-based polymers exceeds growth of the overall polymer market (>6% vs. 4 - 6% CAGR 2020-2025)	
• Production costs could be drastically reduced when waste streams are used as feedstock (almost 50% possible; competitiveness with conventional plastics)	• Downstream processing still a complex and expensive step; needs to be further optimized
• Processes to obtain PHAs from waste streams continuously developed, optimized and promoted. Numerous technologies TRL ≥ 5 already exist	• Commercial processes for producing PHAs from waste streams missing up to now
• PHAs with defined properties can be produced in a tailored manner (change of subunit composition and combination with other materials/ polymers); special applications with higher profit margin conceivable	• Some PHAs such as PHB have unfavorable properties; targeted modification of properties by bioprocesses possible, but not easy to control when using waste streams

Opportunities	Challenges
Environmental aspects see e.g.P1	
• Processes could save GHG, especially when waste streams are used. • PHAs are biodegradable in different environment such as soil, freshwater, marine water but also in home compost, industrial compost, or via anaerobic digestion • Environmental benefits of PHAs could lead to increased demand.	• When waste streams are used, possible risk of making incorrect assumptions regarding e. g. CO_2 footprint; detailed assessment necessary on a case-by-case basis.

2.1 PHA

Opportunities	Challenges
Legal framework P32, P33, P34, P35, P36	
• Regulations on resource efficiency, recycling quotas or emission limits support the development of bio-waste recycling technologies.	• “Waste status” leads to challenges. Corresponding End-of-waste criteria in waste legislation would be helpful - in the best case linked to legally defined chemicals and product properties (REACH and product legislation). • The principle of “Upcycling of waste” as a distinct category into the waste hierarchy is not foreseen.
• Tendency to reduce or even phase out renewable energy subsidies in several EU member states exist; these challenges are pushing AD plant operators to look for new value chains.	• Currently, renewable energy legislation favors energy-oriented AD treatment over waste treatment. • Numerous legally binding acts such as regulations, directives and decisions on quality requirement must be considered when are to be used for e. g. fisheries, cosmetics, food and feed, packaging of food, and medicine (specifications on purity, restrictions on heavy metals, overall migration limits, …).

2.1 PHA

SUMMARY

Although PHAs as bio-based polymers face strong competition in established, mostly fossil-based polymers, the market for PHAs will grow strongly in the coming years. In addition to increased demand for bio-based and biodegradable polymers due to **increasing environmental awareness** and **concerns about human health and safety**, factors such as technical development and legislation will strongly contribute to this growth.

HURDLES

The penetration of the market by PHAs is currently still being significantly **hampered by the high production costs** compared to established petroleum-based processes for plastics. One of the main reasons are **high costs for the feedstock required for PHA production**. In addition, the material performance of PHAs often cannot compete with that of traditional plastics[P1].

CAFIPLA SOLUTION

The processes developed in CAFIPLA precisely address the above-mentioned hurdles: On the one hand, **widely available, extremely cost-effective feedstocks** which are not in competition with food production are used, and on the other hand, the use of mixed carboxylic acids in the single-strain fermentation processes enables **enhanced mechanical properties and improved processability of the resulting PHAs**. The production of bio-composites also obtained by the CAFIPLA technology, will enable further optimization of the PHA properties within the framework of the project.

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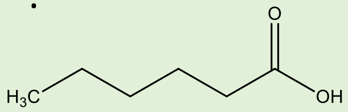
MEDIUM CHAIN CARBOXYLIC ACID

- Group of saturated fatty acids
- MCCAs are straight chain mono-carboxylates with 6–12 carbon atoms including caproate, heptylate, caprylate, etc.,
- Considered to be more profitable than traditional anaerobic products like SCCA (e.g., methane, ethanol).[C1, C2, C18]
- Properties: antimicrobial, energy-rich feed additives, hydrophobicity [C4]
- MCCAs feature higher energy density as well as stronger hydrophobicity than SCCA [C1, C2]
- A common and most attractive MCCA is[C1]: Caproic acid, $C_6H_{12}OH$



In the following chapter, MCCAs and their application are discussed at the beginning, followed by the caproic acid market.

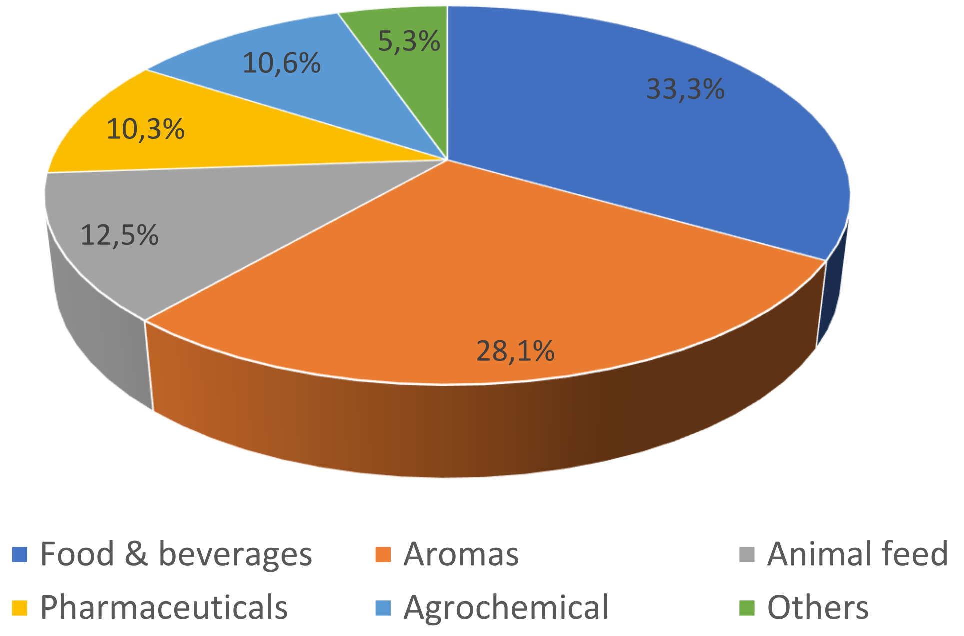
OVERVIEW MCCA - PRODUCTION AND APPLICATION

- MCCA´s including caproic acids are mainly obtained from petrochemical processes or sourced from palm or coconut oil. [C33]
- Main production routes are via upgrading organics like SCCAs, ethanol, and lactate to form less hydrophilic MCCAs using reactor microbial communities. Chain elongation is the primary mechanism for MCCA formation in the fermentation process.[C1]
- As a versatile platform chemical, MCCAs are also used to manufacture products including pharmaceuticals, fragrances, lubricants, rubbers and dyes [C18,C19].
- MCCAs may be processed into liquid biofuels including diesel [C24] and aviation fuel [C22].
- High cost of current MCCAs production limits its large-scale utilization.

MEDIUM CHAIN CARBOXYLIC ACID - MARKET

- The target application of MCCA is depending on
  - the composition
  - quality of the product
  - the raw material.
- Although versatile applications exist, production volumes and market demand of MCCA are still low [C1].
- Current biotechnological enhancement in optimization of MCCA production process promise increase in production volumes and improve product qualities. This could lead to an increase in market demand and target application [C18,C4,C28]
- Total production volume of caproic acid: 0.025 million tons [C28,C29]

GLOBAL CARBOXYLIC ACIDS MARKET SHARE, BY END-USE INDUSTRY, 2018 [C8]



PRODUCTION PROCESSES OF MCCAs AND CAPROIC ACID

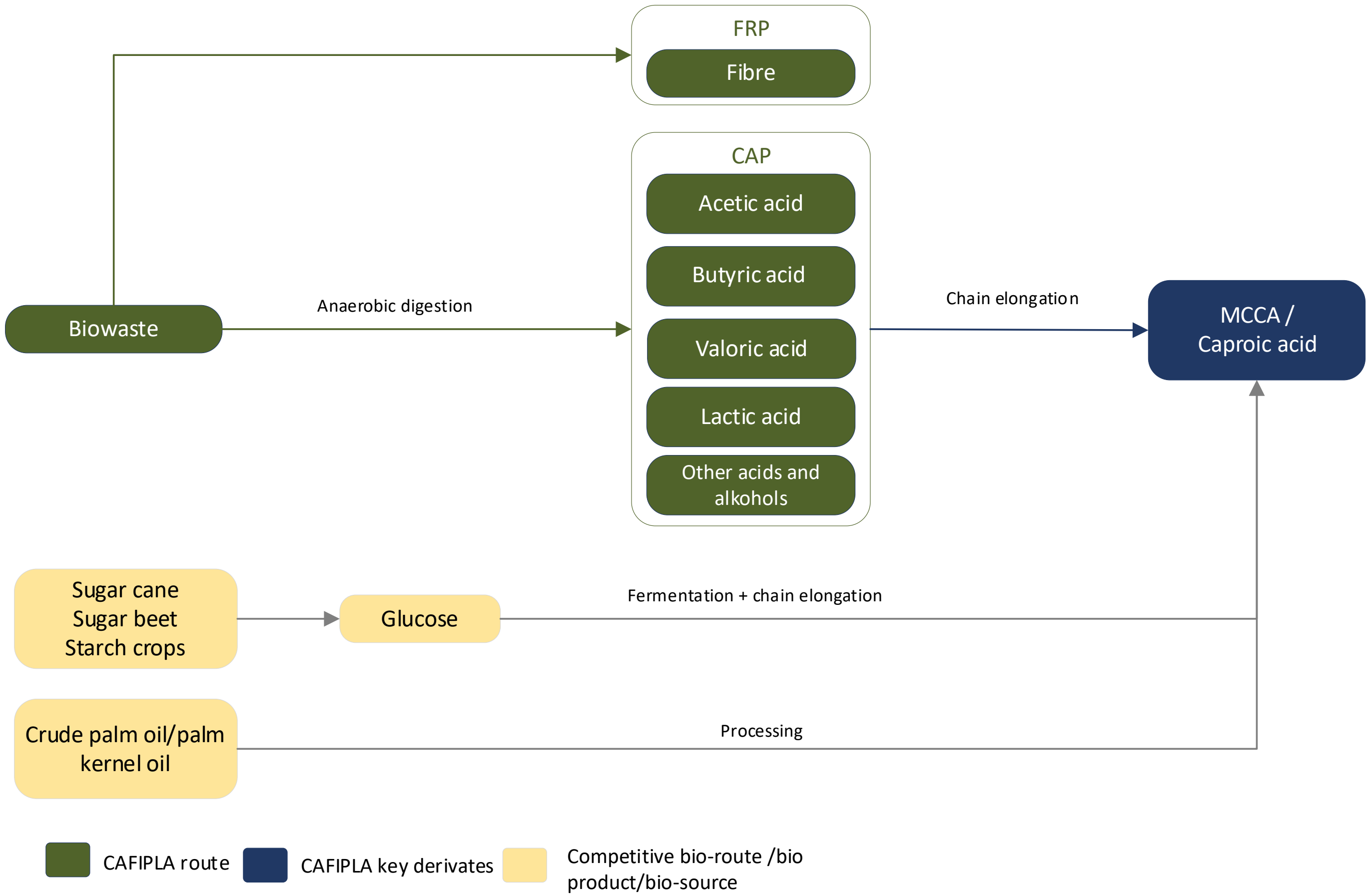
FEEDSTOCK [C18, C19]

Food feedstock
- Palm oil, animal fats, food crops (corn, sugar)

Non-food feedstock
- syngas, biomass, organic waste, liquefied wood flour

COMPETITIVE BIO-PROCESS

- Through hydrolysis and enzymatic treatment, palm oil is broken down into its constituents e.g. caproic acid, caprylic acid and lauric acid. [C20]
- The CAFIPLA technology offers the possibility of switching from a food resource to a non-food feedstock, thus avoiding competition and reducing land use.



Own graphic [c23, C36]

CAPROIC ACID PRODUCERS

Based on references [C6,C8]; supplemented with own research

Producer	Link	Country	Product/Trademark
Emery Oleochemicals	https://www.emeryoleo.com/	Malaysia (Hq)	n.a.
Ecogreen Oleochemicals	https://www.ecogreenoleo.com/	Singapore (Hq)	Ecoric 6/99
IOI Oleochemical	https://www.ioioleo.de/	Germany	Endproduct producer
KLK OLEO	https://www.klkoleo.com	Malaysia, Indonesia, China und Europa	n.a.
Mosselman	http://mosselman.eu/	Belgium	n.a.
Musim Mas Holdings	https://www.musimmas.com/	Singapore	n.a.
Oleon NV	https://www.oleon.com/	Belgium, Brazil, China, France, Germany, Italy, Malaysia, Norway, United Kingdom, USA	Radiacid 0605, Radiacid0696
P&G Chemicals	https://www.pgchemicals.com/	India, Switzerland, USA	C-670, C-6985
Pacific Oleochemicals Sdn Bhd	http://www.pacificoleo.com/	Malaysia	Kortacid 0699
Timur OleoChemicals	https://www.timurnetwork.com/	Malaysia	Caproic Acid C6-98 MY

MARKET DESCRIPTION

Production volume [million tons]

Caproic acid: 0.025 (2013)[C28,C29]

Global market volume 2020 [billion €] [C7,C26,C30]

Carboxylic acid : 8.25

Caproic acid: 0.34-0.45

Price caproic acid [€/ton] [C23, C24,C3]

Unrefined: 830

Refined: approx. 1700-3700

CAGR [%] [C7, C8,C17,C27]

Carboxylic acid market:
4.6-5.4 % (2020- 2025)

Caproic acid
2.9-3.33 % (2020 - 2024)

CAPROIC ACID APPLICATIONS

Application	Usage	Application	Source
Platform chemical	Precursor for many chemicals	Manufacture of its esters for use as artificial flavors and in the manufacture of hexyl derivatives, such as hexylphenols	C4
Daily chemicals	Aromatic	Cheese, yoghurt, butter, goat milk, ice cream	C9, C15, C16
Flavoring and Perfuming Agent	Fragrance (smells like sour fatty sweat cheese)	Alcoholic perfume, Anti-perspirants, Creams and Lotions, Lipsticks, Talcum Powder, tablet soap, liquid soap, shampoo, hair conditioner, bath/shower Gel, Cold Wave, Acid Cleaner, Ammonia chlorine, detergent powder, liquid detergent, fabric softener, candles, pot pourri, incense	C11
Metal working fluid	Corrosion working inhibitors	Metal working fluid	C12, C13
Plastic additive	Plastic softener	Plasticizer	C14
Feed additive	Energy rich fatty source	Feed for pig, piglets, cutlery, poultry	C4,C5

2.2 MCCA AND CAPROIC ACID

Advantages	Challenges
Techno-economic aspects [C4, C28]	
• MCCA and Caproic acid can be used due to its properties in versatile applications. • The conversion from food to the low-cost non-food feedstock bio-waste could lead to lower production costs. Leading to a better price competitiveness would thus increase the market demand of MCCA and caproic acid. Additionally, the environmental benefit resulting from the use of bio-waste as a feedstock could serve as a unique selling point for provision of targeted end products.	• The bio-waste collection as well as the storage methods and facilities are challenging to guaranty waste biomass availability. • To increase the yield quality and quantities, the pre-treatment, the microbial source, the resistance of the microbial communities, the enhancement of the chain elongation and the timely product extraction needs to be improved.

2.2 MCCA AND CAPROIC ACID

Opportunities	Challenges
Environmental aspects[C4, C19, C29]	
• The waste biomass treatment and reutilization leads to a reduction of greenhouse gas emissions, alleviate the environmental pollution and slow down the exploitation of fossil energy. • MCCA and Caproic acid obtained from bio-waste can replace fossil-based or palm-oil based sources and thus provide an alternative environmental beneficial and avoid the competition with food production. • The switch from food and especially palm oil to bio-waste leads to a decreased land use.	• LCA studies show the environmental benefit of caproic acids derived from bio-waste in comparison with caproic acid from palm kernel oil. Nevertheless, studies emphasize need of methodological improvements in environmental comparison for specific application of caproic acid. • Further, influence of fluctuating waste qualities on yield and product purity must be investigated.

2.2 MCCA AND CAPROIC ACID

Opportunities	Challenges
Legal framework [C31, C32]	
• Regulations on resource efficiency, recycling quotas or emission limits support the development of bio-waste recycling technologies. • Tendency to reduce or even phase out renewable energy subsidies in several EU member states exist; these challenges are pushing AD plant operators to look for new value chains.	• In the production of MCCAs and caproic acid for the food industry, special requirements must be met and hierarchy for waste must be observed in the selection of raw materials. In addition, for the cosmetics industry, corresponding REACH requirements must be observed. • The principle of "Upcycling of waste" as a distinct category into the waste hierarchy is not foreseen • Currently, renewable energy legislation favors energy-oriented AD treatment over waste treatment • Numerous legally binding acts such as regulations, directives and decisions on quality requirement must be considered when are to be used for e. g. fisheries, cosmetics, food and feed, packaging of food, and medicine (specifications on purity, restrictions on heavy metals, overall migration limits, …)

2.2 MCCA AND CAPROIC ACID

SUMMARY

MCCA and in particular caproic acid are already used as a fine chemical in the food and cosmetics industry and have a **high potential** to gain more importance in the future, e.g. as platform chemical, feed additive or fertilizer.

The **developments in the field of fermentation are promising regarding strain development and downstream processing** and may ensure a **high yield of high-quality caproic acid** and turn production into a price-competitive process.

HURDLES

Although MCCA and caproic acid the use as fine chemical has already been established in food and cosmetics, the **total volume of caproic acid used in the industry is small**. One reason for this may be - among others - the relatively high market price for refined caproic acid.

CAFIPLA SOLUTION

In general, **anaerobic fermentation** of bio-waste has a **high potential to produce MCCAs** and especially caproic acid as a platform chemical. Within CAFIPLA, a process via a lactic acid chain elongation route is being developed, for which a below-average market price can be expected for caproic acid (very cheap feedstock, improved processes).

This process will be tailored to minimize the loss of lactic acid to competing pathways and to create a selective process for the MCCA as well as caproic acid production.

Furthermore, caproic acid is currently mostly obtained from palm kernel oil. Using bio-waste sources within the CAFIPLA process results in main environmental advantages regarding land use and GHG emissions against the conventional source.

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2.3 MICROBIAL PROTEINS (MPs)

PRODUCT DESCRIPTION

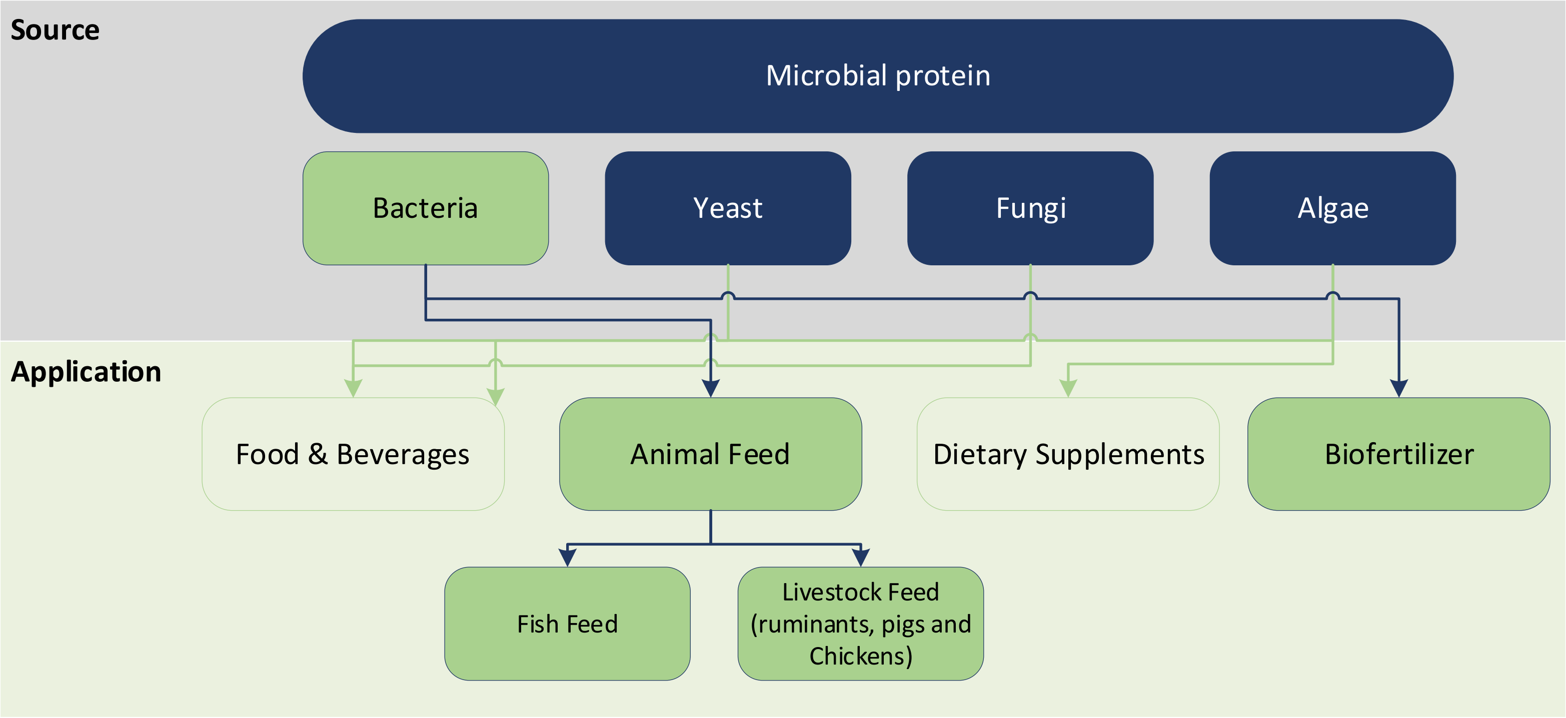
- Microbial (MP) or single-cell proteins (SCP), are defined as high-quality protein additives, which are derived by microorganism as bacteria, algae and fungi including yeast [M1]
- MP is mainly used as an alternative to conventional proteins like casein, soybean meal, egg protein or meat protein in animal feed since it has main advantages as high production rates, protein yields and favorable production properties [M1, M2]
- The quality of MP used for food or feed are described by parameters as the digestibility, the biological value, the protein efficiency ratio and the net protein utilization. [M1]
- Most sources of MP (from yeast and bacteria) have an amino acid profile comparable to fishmeal [M1].
- When comparing the different SCP sources in food or feed application especially parameters as, growth rate, substrate used , contamination and associated toxins are relevant. [M1]

MP	Algae [in% Dry weight]	Fungi including filamentus and yeast [in% Dry weight]	Bacteria [in% Dry weight]
Protein	40–60	30-70	50–65
Fats/Lipids	5-10	5-13	8-10
Ash	8–10	n.a.	3–7
Nucleic acids	4–6	9.7	15–16
Amino acids	N/A	54	65
Nutrional value	Similar to egg, soy and wheat protein.	Amino acids and digestibility of mycoprotein is similar to egg and milk	Amino acids and digestibility is similar to fishmeal

Based on references [M1,3]

MAIN APPLICATIONS

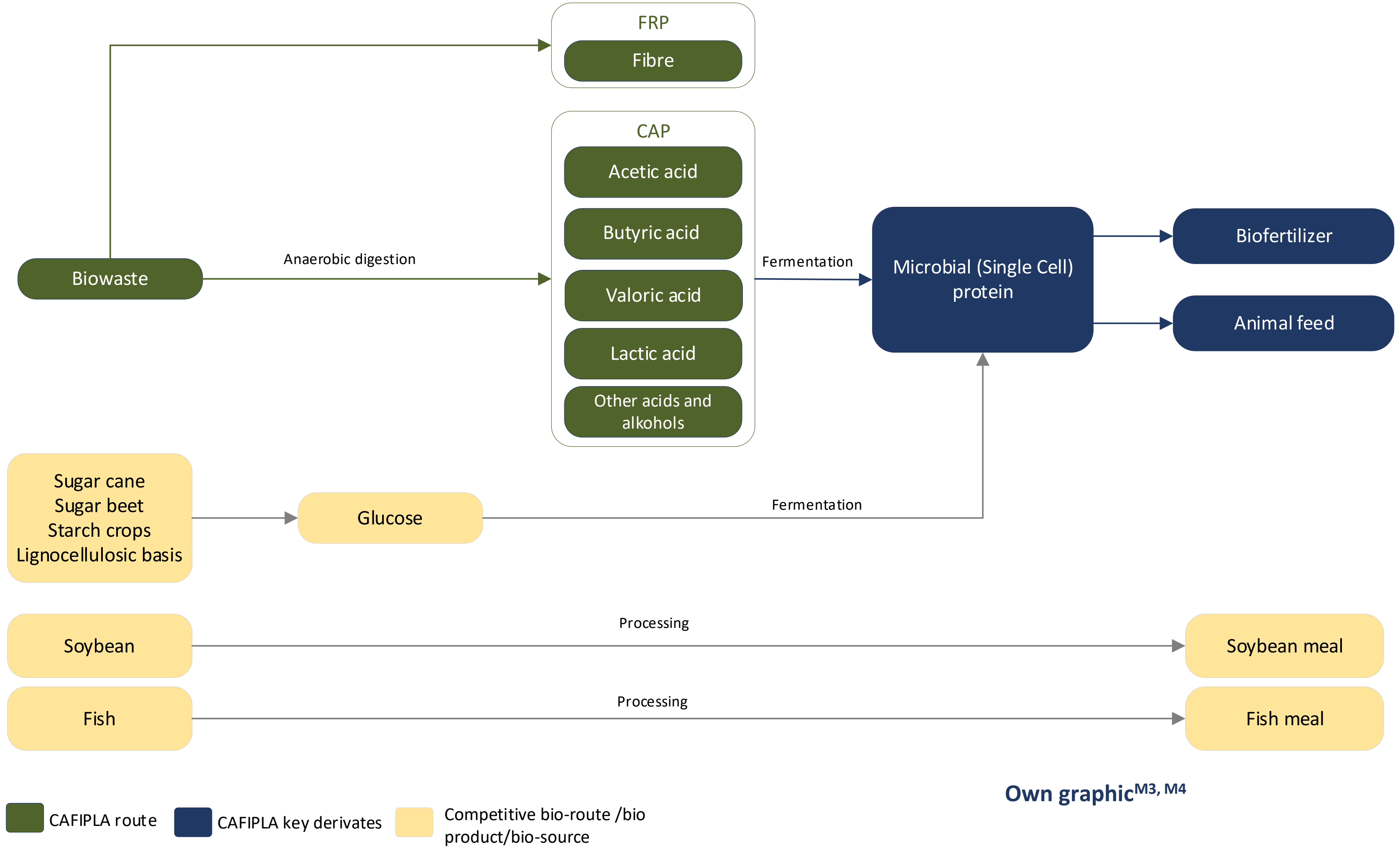
- Based on the source of MP it is used as an alternative source for animal feed (to aquaculture or livestock, including ruminants, pigs and chickens), as biofertilizer and as food and food supplements
- For application as food or feed, especially the nucleic acid content is relevant, which requires further processing due to health issues if it is too high, as it is for bacteria [M1,M3,M4]
- MP is mainly applied as animal feed and microbial biofertilizer
- MP used as fertilizers have an equal performance regarding fertilization, mineralization and storage performance as state-of-the-art organic fertilizer. [M28]



Own graphic based on[M1,M3,M4]

PRODUCTION PROCESSES AND COMPETITIVE ROUTES

- Bacteria based MP is produced on commercially scale hydrocarbon-based using methane as carbon source[M3,4].
- Main commercial products are FeedKind by Calista (USA) and UniProtein by Unibio (UK).
- Current research focusses on production alternatives as to the use of natural or artificial light or molecular hydrogen. Other alternative production routes are the recovery of MP from organic substrates as by-products from various side streams e.g. wastewater from feed and food processing or food wastes[M3]. All this processes are currently under development.
- For MP production mainly single strains are used, thus there is also increased use of mixed populations[M2] as in CAFIPLA



Own graphic[M3, M4]

2.3 MICROBIAL PROTEINS (MPs)

MARKET DESCRIPTION

Global MP/SCP MARKET* [M14,M16]

2020: 4,425 million Euro

2025: 5,481 million Euro

CAGR ~5.1 % (Period 2020 – 2025)

GLOBAL PROTEIN INGREDIENTS MARKET [M15,M19]**

2020: 43.8 billion Euro

2025: 58.9 billion Euro

CAGR of ~6.2% (Period 2020 – 2025)

PRICE PER UNIT:

Dried SCP ~5,000 - 13,400 €/ton[M20]***

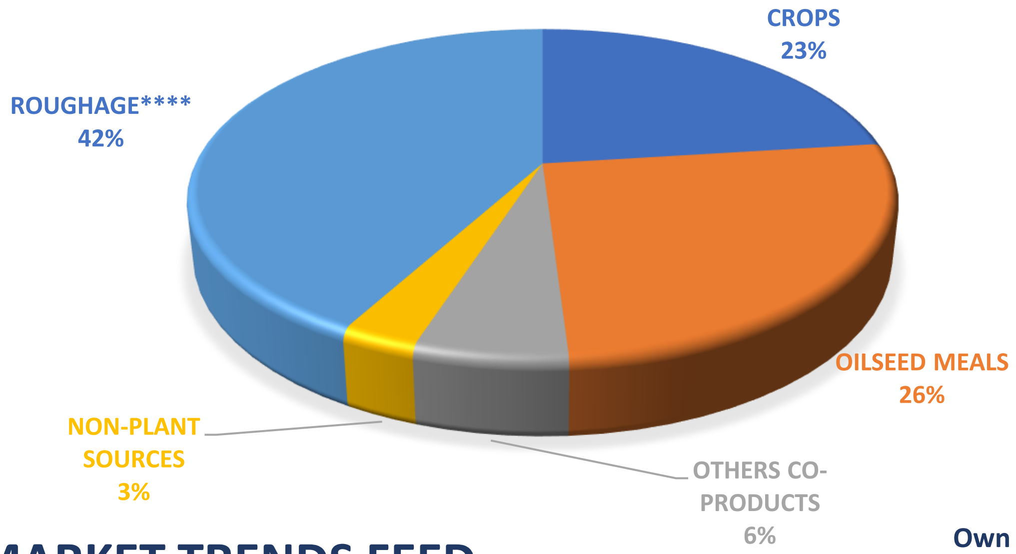
Dried MP (Bacteria) ~1.000 -1.100 €/ton[M9,]

Fishmeal 1,203 €/t[M10]

Soybean meal 413.5 €/t[M11]

*including, yeast, algae, bacteria and others
** including plant an animal protein for application food & beverages, animal feed, cosmetics & personal care and pharmaceuticals.
***retail cost of the SCP product based on electrolysis or coal
**** such as grass and silage maize

EU FEED PROTEIN SOURCES 2021 (FORECAST)



Own graphic based on [M22]

MARKET TRENDS FEED

- Market prospects display a high demand in microbial protein, including protein ingredients market and application as animal feed.
- EU feed protein sources are dominated by roughage, oilseed and crops. According to the EU Agricultural outlook (2021) the demand for feed from arable crops is projected to decrease slightly, mainly due to a decline in EU pig meat production. However, an increase in demand for organic feed is expected due to diversification of livestock and dairy production systems, which is favorable for MP. [M27]

MARKET DESCRIPTION BIOFERTILIZER

GLOBAL BIOFERTILIZER MARKET*[M23,M24,M25]

1.8 billion € (2019)

2.9 billion € (2025)

CAGR ~8.8%

EUORPEAN BIOFERTILIZER MARKET*[M7]

0.26 billion € (2020)

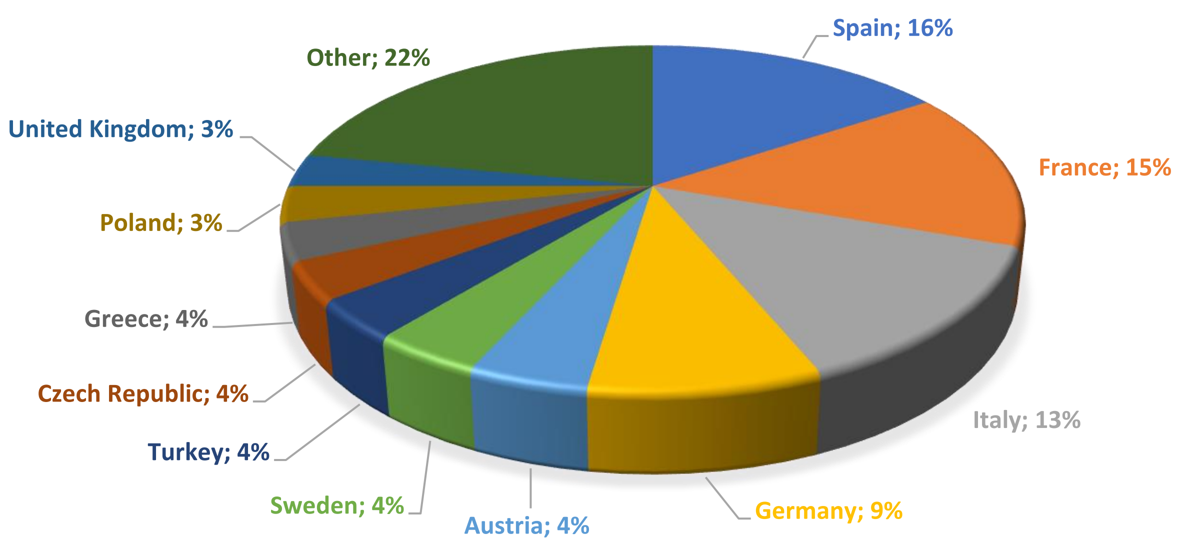
0.45 billion € in (2025)

CAGR ~13,05%

Europe is a relevant player being the second-largest consumer of the global biofertilizer market with a share of ~30 % (2019) [M8]

*including plant an microorganism based fertilizers

ORGANIC CROP AREA BY COUNTRY, 2019



Own graphic based on[M26]

MARKET TRENDS BIOFERTILIZER

- The expected growth of the European biofertilizer market results from higher demand for biofertilizer displayed in an increase of nearly 40% of organic crop area in Europe since 2014. [M26]
- Spain, Italy and France are important players for the biofertilizer market having the highest share in organic farming area. [M8,M26]

MAIN PRODUCERS OF MICROBIAL PROTEIN BASED ON BACTERIA

based on references [M2,M3], supplemented with own research

Main producers	Substrate	Product/Trademark	Country	Links	Production capacity in t DM /a
Avecom	Water from food processing, bio-waste	Valpromic / ProMIC	Belgium	https://avecom.be	Avecom estimate to operate a commercial reactor with a production capacity of 50 tons per year by 2030 of MP based on bio-waste[M9]
Calysta Inc.	Methane	FeedKind®	UK	https://www.calysta.com	First commercial scale plant to be build in China with capacity of 100,000 tons. Currently pilot facility[M13]
CBH Qingdao Co., Ltd	n.a.	MSG By Product	China	http://www.cbhcn.com	n.a.
KnipBio	Methanol	KnipBio Meal	USA	https://www.knipbio.com	Plan was to start commercial production in 2018[M12]

MAIN PRODUCERS OF MICROBIAL PROTEIN BASED ON BACTERIA, CONTINUATION

Main producers	Substrate	Product/Trademark	Country	Links	Production capacity in t DM /a
Lallemand Inc	n.a.	Yeast and bacteria	Canada and France	https://www.lallemand.com	n.a.
Marlow Foods Ltd	Glucose syrup	Mycoprotein Quorn®	UK	https://www.quorn.com.uk	25,000[M3]
Nutrinsic	Waste waters from the food, beverage and biofuel industries to generate feed and fertilizer products	ProFloc®	USA, China	https://www.nutrinsic.com	5,000 from brewery effluent[M3]
UniBio A/S	Natural gas	UniProtein®	Denmark	https://www.unibio.dk	6,000 commercial scale methane to protein plant in Russia[M17]
Vega Pharma Ltd.		Bacteria VEGA Express MSG Protein	China	http://www.vegapharma.com	n.a.

based on references [M2,M3], supplemented with own research

2.3 MICROBIAL PROTEINS (MPs)

OPPORTNITIES	CHALLENGES
TECHNO-ECONOMIC ASPECTS [M1,M2]	
• MP originating from bacteria is convincing especially regarding its high production rates and protein yields. A further advantage lies in uncomplicated production control, which makes MP a respective alternative to conventional plant and animal proteins. • MP addresses many potential markets, including feed and fertilizer market and can be, due to its favourable properties, a substitute for growing demand of conventional agricultural products as animal feed or biofertilizer. • As a by-product of waste valorisation MP could strengthen the economic potential of undervalorised and unprofitable biorefinery side streams, also by means of reducing the downstream processing costs required to dispose of process waste. • Substrate costs are a main factor in MP/SCP production, thus utilizing side- or waste streams for MP production reduces the production costs of MP.	• It competes with traditional agricultural products, which are produced at low cost, as soybean or fish meal. • The MP sourced from bio-waste is hard to dewater and might be necessary to have expensive and extensive dewatering equipment. • If using a bacteria mixture composition, might result in fluctuating characteristics of the end-product. • Removing nucleic acid comes with high costs.

2.3 MICROBIAL PROTEINS (MPs)

OPPORTNITIES	CHALLENGES
ENVIRONMENTAL BENEFITS [M1, M2, M28]	
• The environmental benefit of MP is very high regarding the replacement of conventional, agricultural-based supply for nutritive animal proteins – especially by helping to reduce the pressure on agricultural land and water resources. • LCA studies show, that MP valorised from bio-waste leads to GHG savings in comparison to traditional protein sources as fishmeal or soymeal.	• MP obtained from bacteria has a high nucleic acid content. Thus, it can not be used for human nutrition without relevant extraction processes. A high content of nucleic acids results in negative impacts on human health conditions • The use of waste as raw materials for MP production may be challenging from the safety perspective and may lead to missing public acceptance for direct use as feed or fertilizer source[M2]

OPPORTNITIES	CHALLENGES
LEGAL ASPECTS M29,M30, M31, M32	
• In 2019, the new EU Regulation 2019/1009 on EU fertilising products was adopted regulating CE-labelling and EU-wide marketing for organic fertilisers. Further, the regulation defines relevant contaminants of EU fertilizing products obtained from aerobic or anaerobic digestion processes. By this, the regulation helps to clarify end-of-waste criteria for bio-waste residues. • Tendency to reduce or even phase out renewable energy subsidies in several EU member states exist; these challenges are pushing AD plant operators to look for new value chains.	• Rules on EU legislation for food and feed are very complex. Regarding process waste into feed currently a prohibition applies to certain waste (e.g. household waste fractions, sewage sludge) ((EC) No 767/2009). However, in the last years, the catalogue of feed revealed novel components offering a new future opportunity for e.g. CAFIPLA derived products.

2.3 MICROBIAL PROTEINS (MPs)

SUMMARY

The **high demand for feed and sustainable agricultural production will promote the importance of MP.** Especially advanced product properties as high reproduction rates, amino acid profile and protein content may favor the market demands for application as fertilizer or feed additive.

Further, the **environmental benefits** coming with the use and application of MP, as well as specifically **use of bio-waste as raw material** will promote the demand for MP based solutions, especially in the agricultural sector.

CAFIPLA SOLUTION

CAFIPLA will address the potential risk for the **down streaming processing regarding the specific requirements for the use of MP as feed-additive or fertilizer.** By the potential application of a range of different substrates for bio-waste pre-treatments CAFIPLA will evaluate suitable bio-waste sources for MP production using lab scale fermenters. This may lead **to reduced production cost and will allow tailoring required solutions**, such as protein content and amino acid profile.

HURDLES

Quality of MP for use as feed additive and fertilizer is **highly depending on the amino acid profile and protein content**. Uncertainty appear in this case especially due to the heterogeneity of the used bio-waste. Further, **high production cost, public acceptance and legislative regulations** are main barriers leading to missing acceptance as to conventional alternatives.

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2.4 NATURAL FIBRES

OVERVIEW

- Fibres can be categorized into natural (NF) and man-made fibres (SF).
- Man-made fibre's chemical composition, structure, and properties are modified during the manufacturing process (e. g. regenerated cellulose, polycaprolactam, and polyethylene terephthalate) [F1]
- Natural fibres can be classified by origin: mineral (e. g. asbestos), animal (e. g. wool, silk and mohair) or plant (e. g. cotton, flax, jute) [F2]
- Plant-based natural fibres can be subdivided based on their origin within the plants: seed (kapok), bast (flax, hemp), leaf (sisal), fruit (coir), stalk (wheat, rice) [F2,F3]
- Plant-based fibres mainly consist of cellulose; but also contain varying amounts of substances like hemicellulose, lignin, pectins, and waxes. [F2]

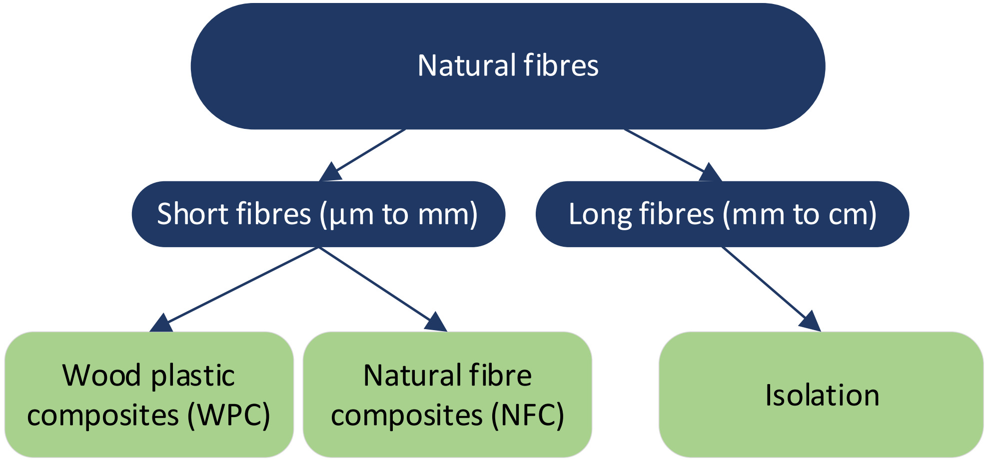
OVERVIEW - PROPERTIES

- Properties of natural fibres substantially varying depending on chemical composition and structure (relating on fibre type, growing conditions, harvesting time, extraction method, treatment and storage procedures) [F7]
- Natural fibre have many advantages towards synthetic fibres due to e. g. low density, good stiffness and strength, good lightweight construction potential and positive break behaviour, low hazard manufacturing processes, low emission of toxic fume, high abundance and availability, recyclability, biodegradability, and low costs [F3,F4,F7]
- Disadvantages towards synthetic fibres : moisture expansion characteristics, lower durability, flammability and variable quality [F4,F7]

2.4 NATURAL FIBRES

MAIN APPLICATIONS

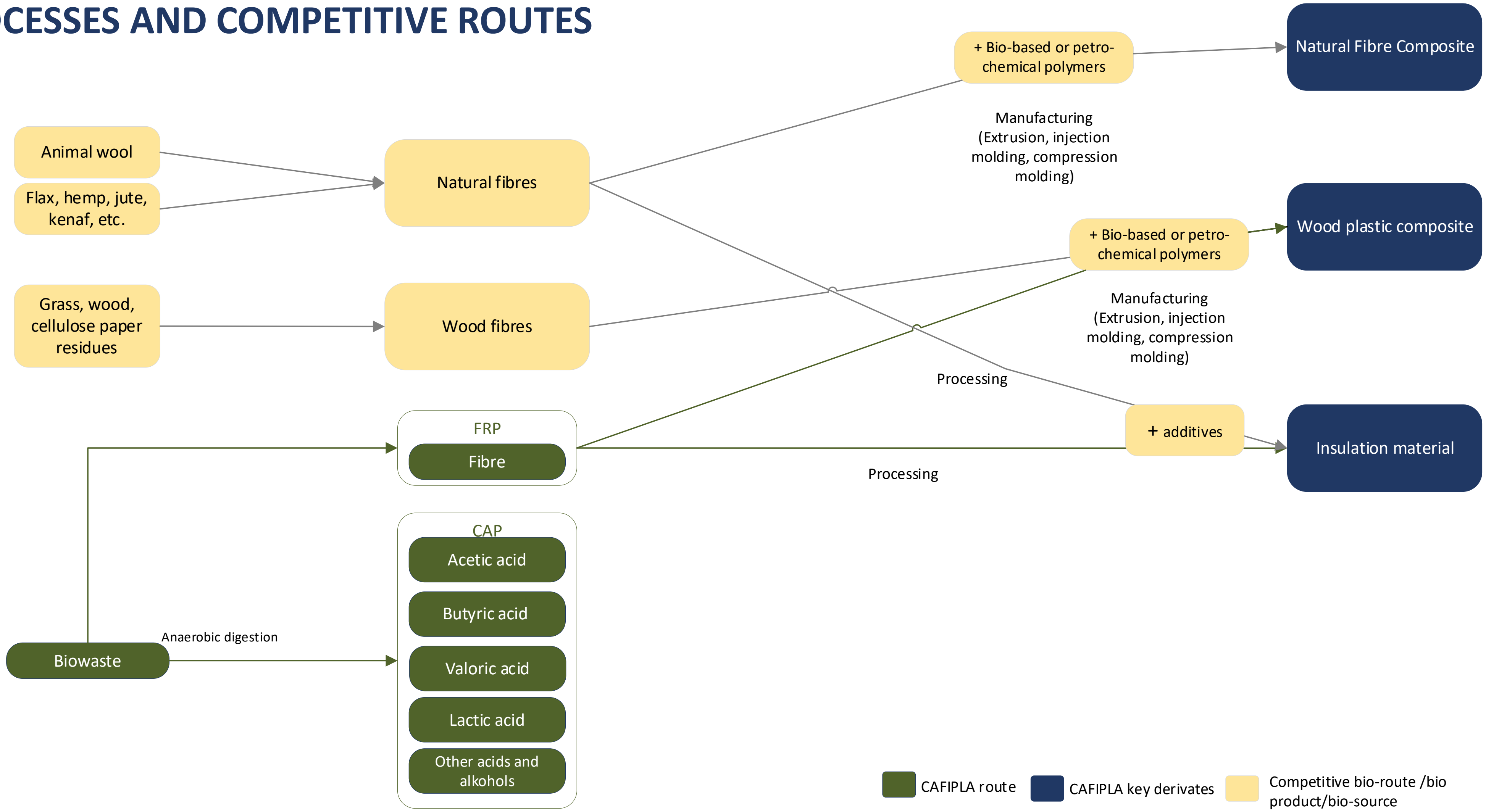
- Both thermoplastic and thermoset polymers can be reinforced with natural fibres (e. g.: polyethylene with rice husk, sisal, sugarcane bagasse or polyester with flax, hemp, sugarcane bagasse) [F8]
- Plant fibres reinforced with biopolymers is an alternative to glass and carbon reinforced composites (e. g. for non-structural and structural parts in aerospace and automotive industries) or are applied for packaging [F12]
- Thermoplastic bio-composites can be processed by standard techniques (injection molding, compression molding, extrusion, thermoforming, pultrusion and resin transfer molding) [F12]



Own graphic based on[F4]

- Natural fibres are increasingly used to produce bio-composites such as Wood-Plastic Composites (WPC) and Natural fibre composites (NFC) and as insulation material. [F4]
- As structural or semi-structural components natural fibre-reinforced composites can be viable substitutions to corresponding synthetic composites, especially in lightweight applications [F6]
- Also used for reduction of purchasing and maintenance costs (e. g. in window and door frames, furniture, railroad sleepers, automotive panels and upholstery, packaging, insulating panels) [F6] and of ecological reason.

PRODUCTION PROCESSES AND COMPETITIVE ROUTES



Own graphic and adapted from[F19]

MAIN PRODUCERS OF WOOD AND NATURAL FIBRES REINFORCED PLASTIC GRANULATE IN EUROPE

Based on references [F18,F24], Year of validity: 2018 supplemented with own research

Producer	Link	Country	Polymer	Fibre	Production volume [ton]
AMORIM	https://www.amorim.com/	Portugal	PP, TPE/TPS, Rubber	Cork	50,000 – 100,000
Beologic	https://www.beologic.com	Belgium	PP, ABS, PBS, PC, PE, PHA, PHB, PLA, PMMA, PS, PVC, SAN, TPE	Wood & natural fibres and others	10,000 – 20,000
Advanced Compounding Rudolstadt	http://www.advanced-compounding.com	Germany	PP, PA, PE, Biopolymers	Different natural fibres, pine	5,000 – 10,000
Tecnaro	https://www.tecnaro.de/	Germany	PP, PBAT, PBS, PE, PLA, Lignin	Wood & natural fibres	5,000 – 10,000
Actiplast		France	PVC, rPVC	Wood & natural fibres	1,000 – 5,000
Admajoris	https://ad-majoris.com	France	PP, Biopolymers	Wood & natural fibres, others	1,000 – 5,000
APM	https://www.apm-planet.com	France	PP, rPP, PBS, Biopolymers, ABS, PVC, TPE	Natural fibres	1,000 – 5,000
Golden Compound	https://golden-compound.com/	Germany	PP, PBS, PBSA	Fibers from sun flower shells	1,000 – 5,000

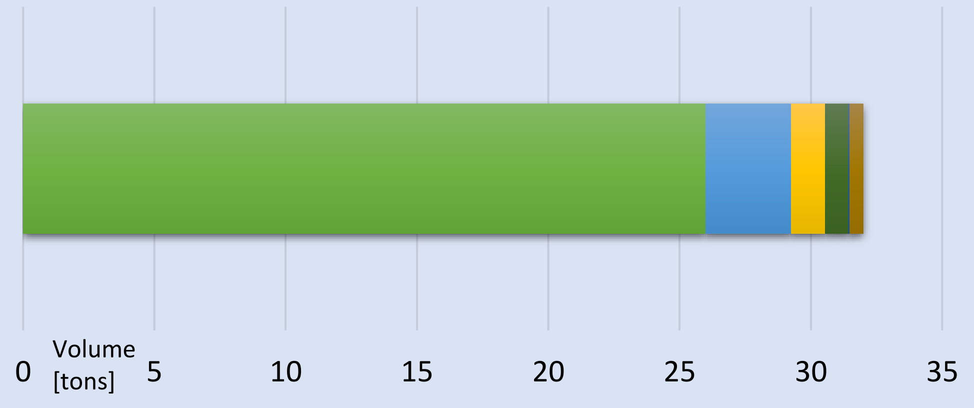
MAIN PRODUCERS OF WOOD AND NATURAL FIBRES REINFORCED PLASTIC GRANULATE IN EUROPE

Based on references [F18,F24], Year of validity: 2018 supplemented with own research

Producer	Link	Country	Polymer	Fibre	Production volume [ton]
Jelu Werke	https://www.jelu-werk.com	Germany	PP, Biopolymers	Wood & natural fibers, others	1,000 – 5,000
Naftex	https://www.naftex.de/	Germany	PA, PP, PLA, Biopolymers	Wood, bamboo, natural fibres	1,000 – 5,000
PlasticWOOD	https://www.plasticwood.it/	Italy	PP, Biopolymers	Wood	1,000 – 5,000
Stora Enso	https://www.storaenso.com/	Finland	PP, rPP, PS, Biopolymers	Wood & cellulose fibres	1,000 – 5,000
UPM	https://www.upm.com/	Finland	PP, Biopolymers	Wood & cellulose fibres	1,000 – 5,000
Biowert	https://biowert.com/	Germany	PP, PE, PLA	Grass fibres, flax	1,000 – 5,000
FKuR	https://fkur.com/	Germany	PP, Bio-PE, Bio-PET, PBS, PHA, PLA	Wood, bamboo, cork, natural fibres	500-1000
Fasal	http://www.fasal.at/	Austria	PP, ABS, Biopolymers	Wood, cellulose fibres, paper, natural fibres	<500

FIBRES MARKET

NATURAL FIBRES 2019 [F9,F11]

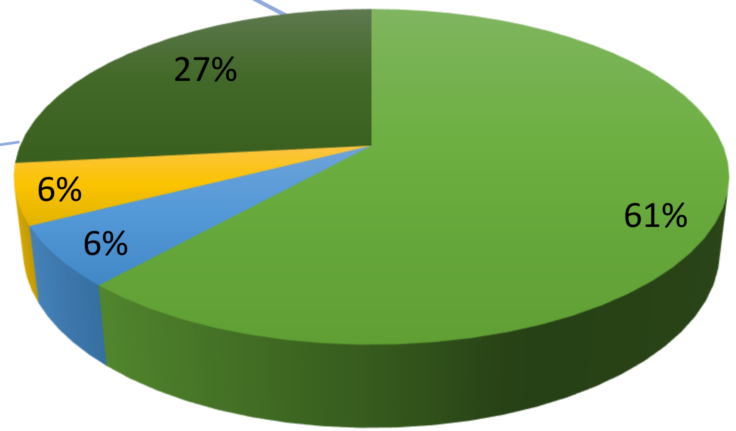


Dynamics 2019 (YOY) [%] [F9]

- **Natural: - 3** *(cotton output falling, bast fibres grown, other natural fibres stable)*
- **Synthetic: + 5** *(robust expansion of polyester filaments and staple fibres)*
- **Manmade cellulosic: + 6** *(viscose staple fibres accelerated, filaments with modest decline and acetate modest growth)*

Global fibre supply 2019 [million tons] [F9]

- **Total: 120**
- **Natural: 32** (mainly cotton)
- **Synthetics: 74** (mainly polyester)



GLOBAL FIBRE SUPPLY [F9,F10]

2.4 NATURAL FIBRES

FIBRE MARKET

Fibre	Price per ton [€] [F20,F21]
Abaca	290 – 830
Bamboo	420
Banana	740
Carbon fibre	12480
Cellulose acetate	3320
Chitosan	16600
Coir	170 – 420
Cotton	1250 – 3490
Flax	1750 – 3490
Glass fibre (E type)	1660
Hemp	830 – 1750

Fibre	Price per ton [€] [F20,F21]
Jute	330 – 1250
Kenaf	259 – 450
Lyocell (and other artificial fibres)	1880
Modal	1950
Pineapple	300 – 460
Polyester fibres	1160
Ramie	1160
Sisal	500 - 1190
Wheat fibre	1370
Wool	8300

COMPOSITE MARKET [F19]

Biocomposites (Europe)	Production Volume 2018 [tons]	Production Volume 2028 [tons] (Forecast)
Decking, fencing & gladding; mainly extrusion	200,000	220,000 – 250,000
Automotive; mainly compression moulding, high shares of natural fibers such as jute, kenaf, hemp	150,000	150,00
Technical applications, furniture, consumer goods, rigid packaging; mainly injection moulding & 3D printing	60,000	120,000 – 180,000
Total	**410,000**	**490,000 – 580,000**

* Uncertainties due to COVID-19 pandemic in end-use sectors such as automotive, building and construction, electrical and electronics, and consumer goods to be considered

CAGR [%]* [F13,F14,F15,F16,F17]

Total composites: 8.8 (2020 - 2025)

Bio-composites: >10 (2020 - 2027)

Wood plastic composites: > 8 (2020 - 2027)

Natural fiber composites: > 5 (2020 - 2024)

Global Volume 2020 [billion €]* [F13,F14,F15,F16,F17]

Total composites: ~ 61,4

Bio-composites: ~ 20.6

Wood plastic composites: ~ 4.3

Natural fiber composites: ~ 5.5

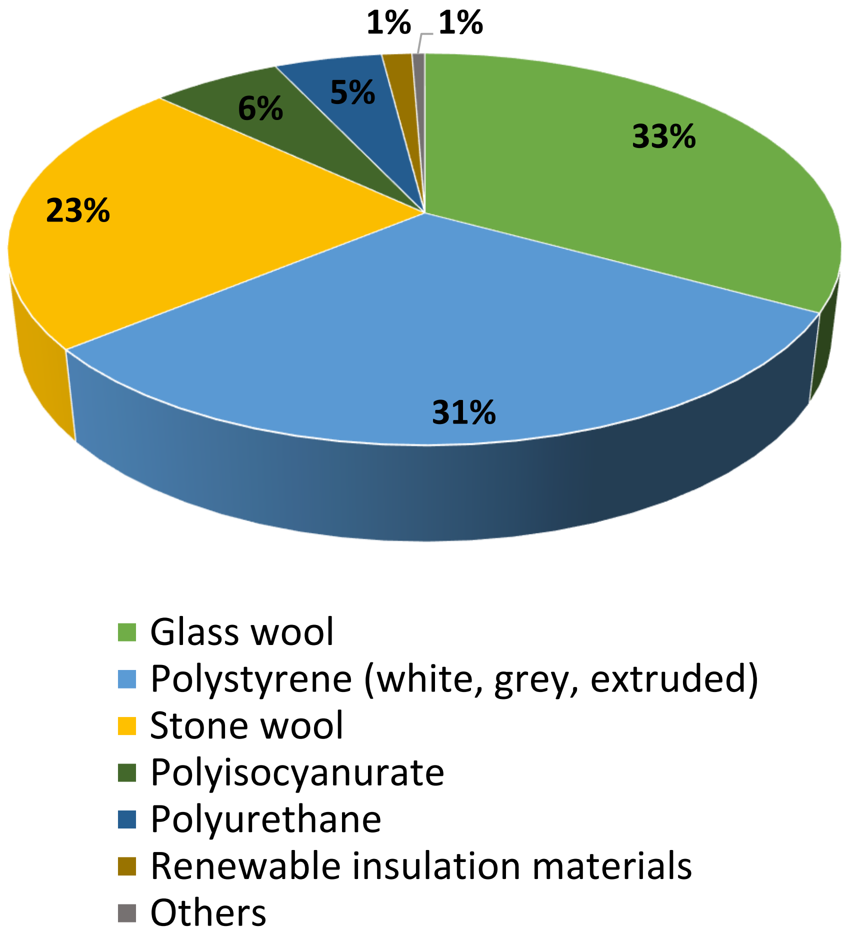
FIBRE INSULATION MARKET

European total market for thermal insulation*: [F22,F23]

Volume [million t]: 10.2
Volume [billion €]: 15.1
CAGR [%]: >2 (2018 – 2023)

* Uncertainties due to COVID-19 pandemic in end-use sectors such as automotive, building and construction, electrical and electronics, and consumer goods to be considered

THE EUROPEAN MARKET FOR THERMAL INSULATION PRODUCTS [F22]



2.4 NATURAL FIBRES

Opportunities	Challenges
Techno-economic aspects F2,F10F12, F21,F23,F24,F25	
• The Composite market shows a steady growth, especially in regard to bio-composite with a CAGR of more than 10% in the next six years. This maybe explained by the high potential of the composite market in Europe, especially regarding the environmental benefit. Further, legislation and an increasing awareness about preserving the planet is expected to play and important role in further boosting the market. • Natura fibres have main technical advantages compared to synthetic fibres such as glass, regarding e.g. the hollow tubular structure. Especially in the automotive sector this properties are favourable for applications such as door/ceiling panels and panels separating the engine and passenger compartments. • The use of natural fiber composites in industries such as automotive is currently driven primarily by price, weight reduction, recycling, less reliance on petroleum resourcesand marketing incentives. • Market developments favorable for bio-composites of many products are the prohibition of conventional plastics in numerous countries (drinking straws and plastic bags). This is especially important for the composite sector which is available for almost every application, including the most important packaging sector. Currently up to 80% of plastics can be replaced by biogenic fillers such as wood flour and cork or by natural fibres for reinforcement.	• Competition with conventional and well-established state-of-the-art fibers already used in the insulation and thermoplastic markets • Technologies' properties challenges of NFC in the automotive sector remain in moisture stability, fiber polymer interface compatibility, and the availability of consistent, repeatable fiber sources. These barriers are preventing them from diffusing into the mass market.

2.4 NATURAL FIBRES

Opportunities	Challenges
Environmental aspects [F4,F21]	
• The environmental impact of the production of natural reinforcement fibres is considerably lower than the impacts caused by synthetic fibres. NFC have in comparison to conventional fibres a lower carbon footprint. The same appears when using natural fibres as insulation. • Recovering fibres from waste streams leads to a better environmental performance, since agricultural land resources are not required.	• Depending on the life cycle steps involved LCA studies show differences in the environmental performance of natural fibres against man-made fibres. Especially, when considering or neglecting the use phase, e.g. the environmental benefits of light weighting can offset higher impacts during the production phase for bio-composite in automobile sector.

2.4 NATURAL FIBRES

Opportunities	Challenges
Legal framework [F2, F24, F25, F26]	
• The Energy Performance of Buildings Directive DIRECTIVE (EU) 2018/844 promotes energy efficiency in buildings across Europe using cost effective measures. Further, it sets new elements and strong political signals on the EU's commitment to modernise the buildings sector. • Herewith, EU countries must establish strong long-term renovation strategies for decarbonising the national building stocks by 2050 with technological improvements.	• Although markets for bio-composites and natural fibres are increasing, the potential of use of e.g. natural fibres as composite reinforcement, is largely depending on increasing of regulation and creating standards for their production and post-treatment.[F2] • Further, substantial political incentives are relevant to increase the bio-based share of the materials used in products, mainly in automotive sector products. [F2] • "Waste status" leads to challenges. Corresponding End-of-waste criteria in waste legislation would be helpful - in the best case linked to legally defined chemicals and product properties (REACH and product legislation) • The principle of "Upcycling of waste" as a distinct category into the waste hierarchy is not foreseen.

2.4 NATURAL FIBRES

SUMMARY

The analysis shows a high demand for bio-composites which is explained by the high potential especially regarding the environmental benefit and saved resource and energy efficiency coming along with the use of bio-composites.

Natural reinforced fibres have main advantages regarding technological and mechanical properties, as weight or price which are especially relevant for the automotive sector.

Environmental benefits are even higher when using fibres recovered from waste sources, since the use of primary agricultural inputs will be decreased.

HURDLES

Although reinforced natural fibres have several mechanical advantages, still important disadvantages remain in moisture stability or fibre polymer interface compatibility.

In legislation, lacking standards for reinforced composites regarding their production and post-treatment hamper further application in targeted sectors, as automotive.

These hurdles may lead to uncertainties for relevant sectors as construction and automotive for promoting market demands.

CAFIPLA SOLUTION

The use of bio-waste as fibre source serves an enormous environmental benefit. **CAFIPLA will enhance fibre valorisation from bio-waste** by firstly **identifying key properties of waste in order to guide recovery ways and fractionation processes**. Further, the process will improve the knowledge on the variability of the recovered fibres and the technological properties for the supplied materials, in accordance with customer specifications.

The methodological innovation in **CAFIPLA can lead to the development of new characterization methods** for dry vegetable fractions from bio-waste.

By this a low-price input material could be used and uncertainties as to quality conditions from market side are addressed and may be reduced.

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3 CONCLUSION (I)

The present initial market analysis provides an overview of the market demand of the CAFIPLA derived products. The initial assessment enables a first evaluation of opportunities and challenges given techno-economic, ecological and legislative aspects of each targeted product and identifies main hurdles and advantages coming with CAFIPLA technology improvements. The assessment derived the following main conclusions for the CAFIPLA targeted products:

- The **PHA** market will grow strongly due to increasing environmental awareness. However, main hurdles are high production costs compared to established petroleum-based processes for plastics and the still lacking competitiveness concerning technical properties with fossil-based alternatives. In this regard, CAFIPLA will provide solutions firstly, using widely available, extremely cost-effective feedstocks which are not in competition with food production. Secondly, the use of mixed carboxylic acids in the single-strain fermentation processes enables enhanced mechanical properties and improved processability of the resulting PHAs.
- **MCCA** and in particular **caproic acid** have a high potential to gain more importance in the future, e.g., as a platform chemical, feed additive or fertilizer. The market demand will increase by developments in the field of processing to ensure high yields of high-quality caproic acid and turn production into a price-competitive process. Nevertheless, main hurdles remain price competitiveness with established products due to low production volumes. CAFIPLA is about to provide a suitable carbon source from a low-price feedstock (bio-waste) for biological MCCA production via the lactic acid chain elongation route. Conditions will be tailored to selective production of caproic acid. In this case, caproic acid production can be provided effectively at high rates and a below-average market price.

3 CONCLUSION (II)

- Due to their favorable production conditions **MPs** have high potentials for increasing market demands specifically if bio-waste is used as raw material. The environmental benefits coming with the use and application of MP promote the market demand for MP based solutions, especially as bio-fertilizer or feed-additive in the agricultural sector. Main challenges remain in the heterogeneity of the used bio-waste, high production cost and lacking public acceptance for use as fertilizer or feed additive. CAFIPLA will tackle these challenges by analysing and evaluating potential application and risks for a range of different substrates from bio-waste pre-treatments. This may lead to reduced production cost and will allow tailoring required solutions, such as protein content and amino acid profile.
- **Fibres** showed high market demand, especially as application for the bio-composites market. High demands are reflected in the high potential especially regarding the environmental benefit and saved resource and energy efficiency coming along with the use of reinforced fibres. Hurdles for targeted application markets remain in uncertain quality as to mechanical properties. CAFIPLA can provide not only an alternative low-price and resource-saving source for fibres but will rather enhance the quality of incoming raw materials by improvement of bio-waste characterization methods.