NC PARTNERING

BIOREFINERIES IN EUROPE

Preface

'Biorefineries in Europe' is a study conducted by the Confederation of European Paper Industries (Cepi). This is the first time such detailed information has been collected and compiled on forest-based biorefineries at the European level. The study was conducted between the months of February to November 2020, which coincided with the COVID-19 pandemic which, of course, was continuing even as the study was completed. Like any other activities, the pandemic also affected implementation of the study.

We'd like to thank the Cepi Mirror group for its help and guidance during the study. Input from the Mirror group has been invaluable in getting the study completed. The Cepi Mirror group consisted of Antti Tahvanainen (Finnish Forest Industries), Sverker Danielsson, (Swedish Forest Industries), Renate Kepplinger (Austropapier), and Annita Westenbroek (Royal VNP). Together we set a frame for this unprecedented study.

The project team consisted of experts within NC Partnering network including Mark Rushton, Daniel Paul Dima, Anna Nikkilä, Aimo Mustamäki, Tuomo Niemi and Stefan Fors. Special thanks belong to Professor Olli Dahl from Aalto University, who helped us to navigate between different bio-based products.

We'd also like to thank Bernard Lombard, Cepi Trade & Industrial Policy Director, who has facilitated the cooperation within the industry and with the pulp and paper associations across Europe, as well as assisting with his expertise and securing regular communications as the study progressed to its conclusion.

On behalf of project team,
Jukka Kantola

Executive summary

Background

Cepi launched its 2050 Roadmap in 2011. With it came a proposal that by 2050 Europe's forest fibre industries would be decarbonised by 80%, while creating 50% more added value. In November 2019, European pulp and paper industry CEOs declared their intention to be at the forefront of the 2050 decarbonisation efforts by reducing the impact of their operations on climate change, while also increasing production in Europe. The CEOs outlined their plans to contribute to a climate-neutral Europe by 2050. The contribution of forests as a net sink and the substitution of fossil-based materials and fossil energy will help meet this challenge.

In the future, a growing share of the added value generated by the industry will come from bio-based products other than pulp and paper. European pulp and paper companies are developing more and more business related to new bio-based products, as a complement to their 'traditional' bio-based products. Recently, some major investments in new and existing biorefineries were announced and some are now moving towards implementation.

The objective of this first wood-based biorefinery study is to register biorefineries in Europe and identify what products they produce. Also, the goal was to identify the value of the new bio-based products.

The goals of this study are to:

1) *develop a robust methodology*
2) *draw an exhaustive list of existing and planned biorefineries connected to chemical pulp manufacturing and recycling in Europe and identify what products they produce and*
3) *provide estimates about investments, turnover, added value and jobs*.

The target of having these insights is to get informed and inspired about the opportunities to expand the valorisation of wood further than only pulp and paper products, thus contributing to the Cepi 2050 roadmap by increasing the added value of the sector.

Methodology

The study was executed in 4 steps

- STEP1 – Defining the scope, Biorefinery concept, bio-based products
- STEP2 – Data Collection
- STEP3 – Data analysis
- STEP4 – Conclusions and reporting

Data analysis was carried out during October 2020 and the reporting and the conclusions of the study were completed in November 2020.

To identify the potential direction of the industry, R&D programs were also analysed. The analysis mainly relied on a Forest-based Technology Platform (FTP) database. Status analysis was completed by questionnaires for the major institutes in Europe.

Biorefineries and bio-based products definitions and segmentations were agreed on in April 2020, which gave a frame for data collection. Data collection was based on public sources and was completed by questionnaires sent to forest industry companies. The survey was conducted during the summer and autumn 2020.

Definitions

In the study we used following general definition for biorefineries:

A biorefinery is an overall concept of a processing plant where forest-based feedstock* is converted and extracted into a spectrum of added value products.

****virgin and/or recycled fibres***

In order to collect relevant information on biorefineries we used the following sub-categories:

Category 1: Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products
Category 2: Biorefineries using virgin pulp and/or recycled fibres to produce evolving bio-based products
Category 3: Other biorefineries using lignocellulose as raw material to produce various existing or evolving bio-based products

The main interest was on active biorefineries i.e. those which are already in commercial production and the biorefineries in the survey are related to the pulp and paper industry. Planned biorefineries considered needed to meet the following criteria: *they have to have been publicly announced, have a location, a credible organisation to execute plans, or at a mature stage, (for instance already holding permits), investment cost indicated, and start-up year announced (in general within a 3 or 5-year horizon).*

R&D programs are more open and do not necessarily always lead to investments. In this study R&D programs were analysed to see in which directions the industry might develop.

In all cases the feedstocks are of primary ***forest origin*** (wood). Bioproducts are classified as materials, chemicals, fuels, food/feed, pharmaceuticals and cosmetics and can be both for commercial and internal use. Classification follows Cepi's definition from 2017 (Appendix 1).

The value of the biorefinery sector is derived from the volumes of identified bio-based products combined with the current market prices for each product. Market prices are based on the NC Partnering database.

Results

In the study, 139 biorefineries were identified and most of them were based on chemical pulping (84%). Also, a total of 28 planned biorefineries were listed. The planned biorefineries share of new types of processes (other than chemical pulping based, or paper production based) is becoming more substantial, being 16% of the total. The turnover generated by other biobased products than pulp and paper is still rather small, being close to €2.7 billion, which corresponds to slightly less than 3% of European pulp and paper industry sector turnover as a whole. Based on investment plans and R&D programs it is justified to expect the share of emerging bio-based products to be substantially larger in the future.

Most common bio-based products – based on volumes

1) *Commercial production*
   - Man-made fibres
   - Biodiesel
   - Lignosulphonate
2) *Planned*
   - Biodiesel and naphtha
   - Lignin oil
   - Biochemicals

Most common bio-based products – based on value (in terms of turnover)

1) *Commercial production*
   - Man-made fibres
   - Tall oil products
   - Biodiesel and naphtha
2) *Planned*
   - Biodiesel and naphtha
   - Biochemicals
   - Lignin oil

Disclaimer

This report has been based on the data available at the time of its writing.

Data is sourced from company reports and interviews, press releases, and other public sources. During the study, a survey regarding new bio-based products was conducted with companies in the industry. Data gathered from this survey has also been used. If no data has been available, estimates based on the NCP database have been used. The market prices are based on the NCP database.

Some countries can be partially overrepresented due to active participation to the survey conducted during the study.

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1 Introduction

Cepi launched its 2050 Roadmap in 2011. With it came a proposal that by 2050 Europe's forest fibre industries would be decarbonised by 80%, while creating 50% more added value. In November 2019, European pulp and paper industry CEOs declared their intention to be at the forefront of the 2050 decarbonisation efforts by reducing the impact of their operations on climate change, while also increasing production in Europe. The CEOs outlined their plans to contribute to a climate-neutral Europe by 2050. The contribution of forests as a net sink and the substitution of fossil-based materials and fossil energy will help meet this challenge.

In the future, a growing share of the added value generated by the industry will come from bio-based products other than pulp and paper. European pulp and paper companies are developing more and more business related to new bio-based products as a complement to their 'traditional' bio-based products. Recently, some major investments in new and existing biorefineries were announced and some are now moving towards implementation.

The objective of the study is to register biorefineries in Europe and identify what products they produce. Also, the goal was to identify the value of the new bio-based products.

The goals of this study are to:

1) *develop a robust methodology*
2) *draw an exhaustive list of existing and planned biorefineries connected to chemical pulp manufacturing and recycling in Europe and identify what products they produce and*
3) *provide estimates about investments, turnover, added value and jobs*.

The target of having these insights is to get informed and inspired about the opportunities to expand the valorisation of wood further than only pulp and paper products, thus contributing to the Cepi 2050 roadmap by increasing the added value of the sector.

The study was launched in February 2020 and was completed in October 2020. The owner of the study is Cepi and service provider was NC Partnering Ltd. The study was supported by a Cepi Mirror Group with experts from Cepi member associations from Austria, Finland, The Netherlands and Sweden.

2 Background of the study

The scope of the study included the following:

The study focuses essentially on biorefineries related to pulp and paper manufacturing, and more precisely chemical pulping, paper mills, and new technologies (defined in chapter 4). Chemical pulp manufacturing and recycling are within the scope of CEPI's membership, which is composed of pulp, paper and board producing companies.

The study includes the most recent data and allows for periodical updates

The aim of the study is to collect a robust database on biorefinery developments, which does not only depend on 'official sources' of information. The study is also a contribution to the CEPI 2050 Roadmap.

The aim of the study is to identify emerging bio-based products in the EU27, the UK, Norway and Switzerland.

Firstly, it was decided what constitutes a 'biorefinery' and what are the various categories. Definitions for other bio-based products were agreed within Cepi and the Cepi Mirror Group in April 2020 and they are described in full in chapter 4 of this report.

Current pulp and paper products are obvious bioproducts themselves and are already well established. These are already well listed and reported by existing Cepi statistics. So, in the European biorefinery study, they were not part of the scope.

Instead the focus was to identify emerging new bio-based products, which are not currently covered by Cepi statistics. It was decided to use an earlier definition of bioproduct categories defined by Cepi (Appendix 1) as a tool to differentiate product areas. Bioproduct categories and bio-based products are defined in chapter 5.

Final results are to be integrated to Cepi's current database on bio-based products – existing and emerging.

3 Methodology

The methodology used in this study was divided into three (3) steps.

In step one (1), information for three biorefinery categories and their new bio-based products (detail listed in Chapter 4, Definition of Biorefinery), was collected using public information available from sources like the Internet, national pulp and paper associations, OECD reports, national statistic reports, EU studies on the bioeconomy – e.g. BBI reports – and also using the NCP database. All data were collected into an Excel file, where information was presented country by country in Europe (EU27, UK, Switzerland and Norway).

In step two (2) additional information on new bio-based products was requested from the companies who have activities in Europe with a web-based survey organised by Webropol[1], the service provider. The categories of new bio-based products were classified using the definitions set by Cepi[2]. The categories are: materials, chemicals, fuels, food/feed and cosmetics/pharmaceuticals for commercial and internal use. It was also pointed out in survey that:

- *In all cases the main part of the feedstock is of primary forest origin (wood fibres)*
- *All biorefineries in the study are related to Cepi members' interest*
- *Facilities listed need to be in commercial production or planned by known industrial operator(s) or investor(s)*

In addition to Cepi's definitions, NCP also used biorefinery definitions from step one (1) and presented certain bio-based products as examples in each category. The attained information from this web-based survey was listed in the same Excel file presented in step one (1) to crosscheck all information.

[1] https://webropol.com/
[2] Key definitions by CEPI (Appendix 1)

In step three (3) a new web-based survey organised by Webropol targeted the institutions (universities and research centre organisations) in Europe, which develop new bio-based products in their research projects. The format of the survey was similar to those used in step two (2). These results are presented in Chapter 7 (R&D programs and consortiums of the evolving bio-based products).

Finally, the value of the emerging bio-based products is evaluated at European level. This is based on volumes of emerging bio-based products collected via step 1 and step 2 combined with price information of the bio-based products. There is no single source for emerging new bio-based products, so in the study price estimates are collected from various sources and derived from the NC Partnering database.

The scope of the study was to identify biorefineries and bio-based products in Europe including EU27 + Norway, UK, Switzerland. These locations were identified. Most of the forest industry is located in 18 countries which have associations and are members of Cepi. Any comparison on values and other numbers are done respectively within the areas.

4 Definition of biorefinery

4.1 General

Several definitions of what a biorefinery is have been elaborated in the last decades. According to the **US DOE**[3], a bio-refinery is intended as "an overall concept of a processing plant where biomass feedstock is converted and extracted into a spectrum of valuable products".

Other sources define a biorefinery as a more specific concept, more closely derived from the concept of an oil refinery in the petrochemical industry. For instance, a biorefinery is defined by **de Jong et al.** (2012)[4] as the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat), using a wide variety of conversion technologies in an integrated manner. This definition is also employed by the Bio-based Industry Consortium[5].

BIC[6] defines a biorefinery as an integrated production plant using biomass or biomass- derived feedstocks to produce a range of value-added products and energy.

The EU's Joint Research Centre (JRC) produced an interesting research brief[7] in 2018: 'Bio-refineries distribution in the EU'. It lists 803 bio-refineries and covers the production of bio-based chemicals including platform chemicals, solvents, polymers, paints, coatings, inks, surfactants, cosmetics, adhesives, lubricants, plasticisers, stabilisers, enzymes and agrochemicals, among others, liquid biofuels (including bioethanol, biodiesel and bio-based jet fuel among others), bio-based composites and fibres including wood-plastic composites, natural fibres

[3] US DOE, 1997, Energy, Environmental and Economics (e3) Handbook, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Washington D.C.
[4] de Jong, E., Higson, A., Walsh, P., Wellisch, M., 2012. Bio-based Chemicals. Value Added Products from Biorefineries - Task 42 Biorefinery. http://www.ieabioenergy.com/publications/bio- based-chemicals-value-added-products-from-biorefineries. IEA Bioenergy - Task 42 Biorefinery
[5] https://biconsortium.eu/news/mapping-european-biorefineries
[6] Bio-based Industries Consortium
[7] Biorefineries distribution in the EU Research Brief, 2018.

composites and different types of fabrics, among others and other types of energy derived from biomass including electricity, heat and gas. 201 bio-refineries appear to be related to forestry. This is very good material, however, detailed data are not publicly available.

In the study we are using general definition for the refinery as follows:

A BIOREFINERY IS AN OVERALL CONCEPT OF A PROCESSING PLANT WHERE FOREST-BASED FEEDSTOCK* IS CONVERTED AND EXTRACTED INTO A SPECTRUM OF ADDED VALUE PRODUCTS.

virgin and/or recycled fibres

In order to ensure holistic data collection, we divided biorefineries into three categories, which are used to classify different types of biorefineries relevant to Cepi and its members. The same classification is to report the results.

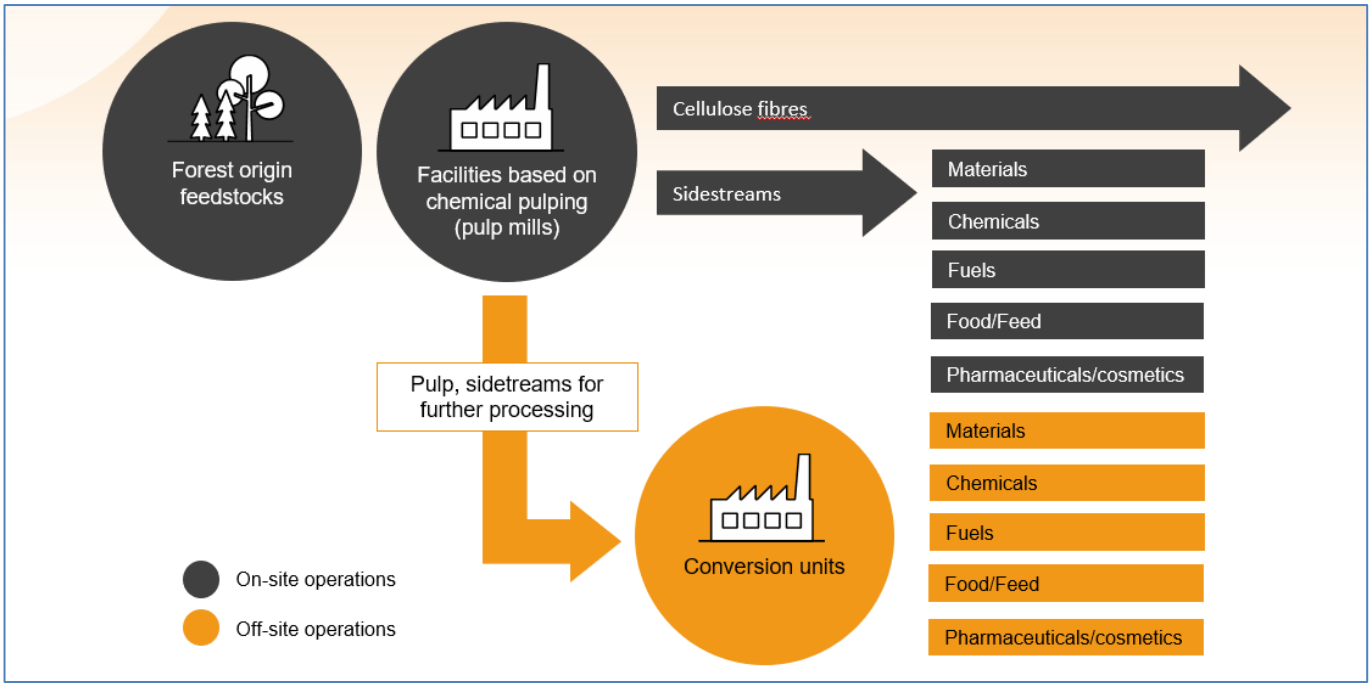
4.2 Category 1

Category 1: Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products, fig. 1.

Biorefineries are mainly chemical pulp mills producing bio-based products alongside the traditional fibres for paper, board, tissue, dissolving pulp etc. The pulp process may be kraft, sulphite, alkali, etc. and maybe in the future based on Deep Eutectic Solvents (DES).

The primary pulping process is to refine wood components to cellulose fibres for further processing. Further processing can be on-site (integrated model) or as a separate facility (non-integrated model).

Figure 1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products.



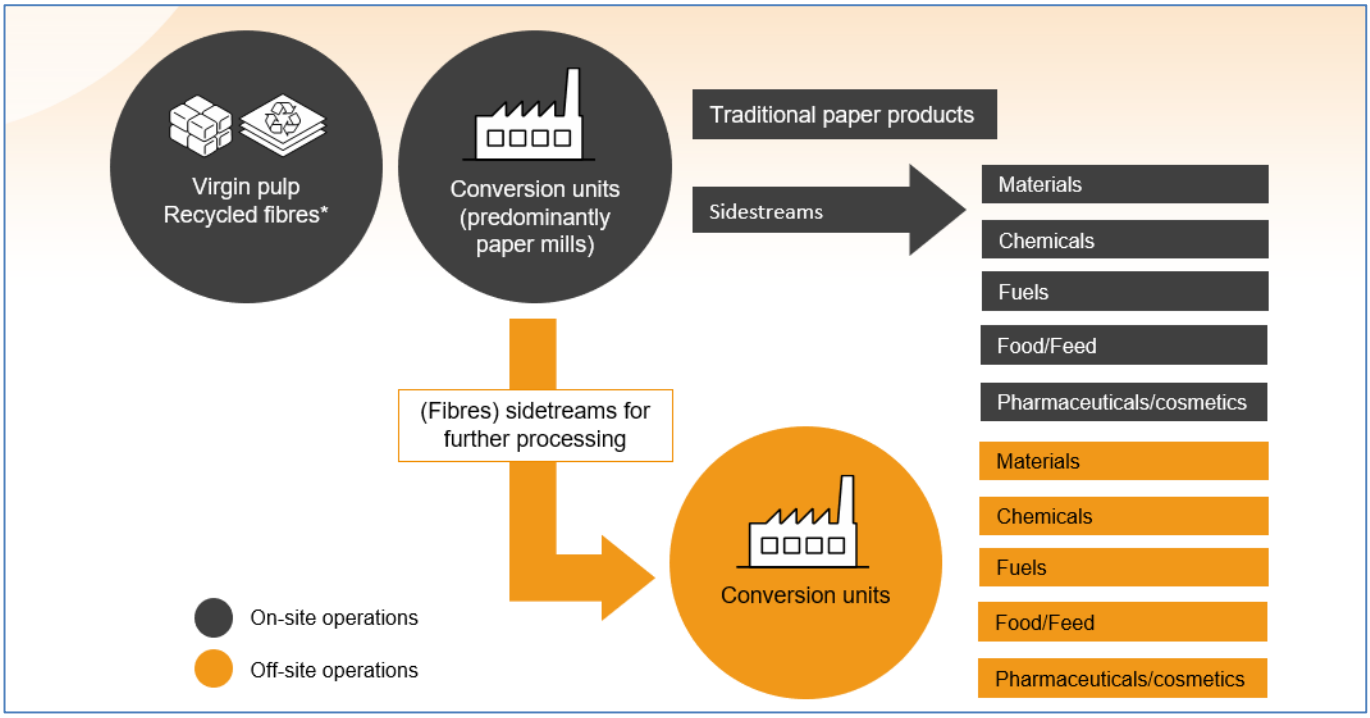
4.3 Category 2

Category 2: Biorefineries using virgin pulp and/or recycled fibres to produce evolving bio-based products, fig. 2.

Today's papermaking plants are mainly producing paper, board and tissue manufacturing as integrated processes. Some side streams of the papermaking processes are converted to new applications.

Value chains for paper, board and tissue are generally well established. At some point there will be a possibility for side streams to be used for producing emerging bio-based products within integrated or non-integrated conversion units.

Figure 2. Biorefineries using virgin pulp or/and recycled fibres to produce evolving bio-based products.



4.4 Category 3

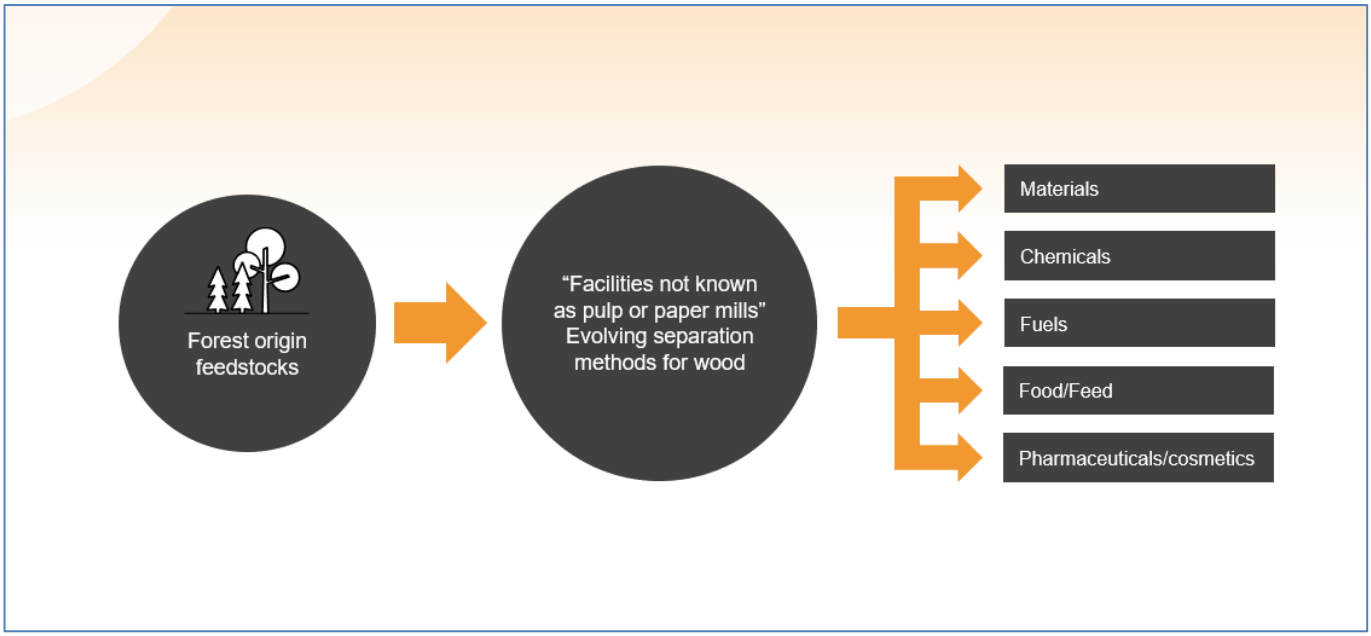
Category 3: Other biorefineries using lignocellulose as raw material to produce various existing or evolving bio-based products, fig. 3.

This category is dedicated to defining new types of separation methods for wood refining.

Units are comparable to pulp mills, but are based on different types of processes, using chemical, thermochemical, mechanical and/or physical treatments/reactions. Although the unit considered under Category 3 are not connected to pulp and paper mills, they belong to pulp and paper companies.

Separation technologies are for instance using hydrolysis, fermentation, enzymatic treatment, steam explosion etc.

Figure 3. Other biorefineries using lignocellulose as raw material to produce existing or evolving bio-based products.



5 Emerging bio-based products

5.1 General

In all cases the feedstocks are of primary forest origin (wood). Bio-based products are classified as materials, chemicals, fuels, food/feed, pharmaceuticals and cosmetics and then can be both for commercial and internal use. Classification follows Cepi's definition from 2017 (Appendix 1). Cepi has also compiled a comprehensive poster publication on wood-based products and intermediate products (What tree can do?), which is presented in Appendix 2.

Emerging bio-based products can be used as either intermediates or as final products. They all have a position in the value chain even if sometimes they are further processed by the user, for example, as a business-to-business product - or they are used by consumers as an end product, for example, as a business-to-consumer product. In this survey both intermediates and end products have been identified and classified as per Cepi's definition.

5.2 Materials

Materials are classified by Cepi as follows: natural fabric, dyes, pig iron, asphalt, roofing sheets, carbon fibre, thermoplastics, synthetic viscose fibre, alternatives to metallic materials, bio-plastics, cellulose foams, flexible and LCD screens, etc. In this study the defined materials are listed in more detail:

5.2.1 Biochar

Biochar is a charcoal-like substance that is made by burning organic material from agricultural and forestry wastes (also called biomass). Biochar is made by a controlled process called pyrolysis with low oxygen, or dry distillation.[8] Another method to produce biochar-like material is hydrothermal carbonisation treatment (HCT). This method can be used for upgrading biomass for solid fuel or material applications when the raw material includes a lot of water. Typical raw material in the pulp and paper sector is sludge from wastewater treatment.

5.2.2 Bio-composite

A composite material (also called a composition material or shortened to composite, which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. [9] In this context the composite is material made of a polymer matrix reinforced with wood fibres called fibre-reinforced plastic (FRP) or fibre-reinforced polymer.

5.2.3 Cellulose nanofibres

Cellulose nanofibres (CNF) also called nanofibrillated cellulose (NFC). CNF also includes bacterial cellulose, which refers to nano-structured cellulose produced by bacteria. CNF is a material composed of nanosized cellulose fibrils with a high aspect ratio (length to width ratio). Typical fibril widths are 5-20 nanometers with a wide range of lengths, typically several micrometres.

CNF suspensions are pseudoplastic and exhibit thixotropy. The property of certain gels or fluids that are thick (viscous) under normal conditions but become less viscous when shaken or agitated. When the shearing forces are removed the gel regains much of its original state. The fibrils are isolated from any cellulose containing source including wood-based fibres (pulp fibres) through high-pressure, high temperature and high velocity impact homogenization, grinding, microfluidisation or with appropriate enzymatic or chemical treatments, such as TEMPO-mediated oxidation.

5.2.4 Kraft Lignin

Lignin is a wood substance, an aromatic polymer found in the cell wall of plants and is the binding substance in natural fibres. Lignin is dissolved out along with the carbohydrates in the pulping process.[10] Kraft lignin is a lignin separated from kraft black liquor via acidification processes, for example LignoBoost[11]. Kraft lignin is mainly used today as a fuel in the lime kiln to replace fossil fuels.

Modified lignin can be suitable for several industries such as automotive, construction, coating, plastics and pharmaceutical industries. Refined lignin can replace oil-based phenols used in resins for plywood, OSB, LVL veneer, paper laminate and insulation material. Other possible future uses are carbon fibre and coal used for energy storage.[12]

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[8] https://regenerationinternational.org/2018/05/16/what-is-biochar/
[9] https://www.textileschool.com/
[10] https://sustainability.cepi.org/glossary/
[11] https://www.valmet.com/media/articles/up-and-running/new-technology/PEERS1stLignoBoostPlants/
[12] https://www.storaenso.com/fi-fi/products/lignin

5.2.5 Man-made-fibres

Man-made fibres (MMF) are as described, fibres made by man. MMF can be organic or inorganic. Organic MMF can be made from natural materials like wood or made from synthetic polymers.[13] In this survey all the MMF listed are wood based.

5.2.6 Microfibrillated cellulose

Microfibrillated cellulose (MFC) is produced by mechanical treatment with or without enzymatic or chemical pre-treatment. The material consists of long and thin fibres which form a three-dimensional network, and these fibres have crystalline as well as non-crystalline segments. MFC water suspensions possess high viscosity and yield stress, it is shear thinning and has high water holding capacity. The size distribution of the fibres is wide, and even if some fibres have diameters in nanoscale, there are a lot of bigger fibres as well. Moreover, the fibres are in a network structure and interconnected to each other (it depends on the concentration of the suspension).[14]

5.2.7 Nanocrystalline cellulose

Nanocrystalline cellulose or cellulose nanocrystals are produced from a native cellulose source, and are abundant, renewable and biodegradable. They can be obtained from native fibres by an acid hydrolysis, giving rise to highly crystalline and rigid (rod like) nanoparticles which are typically 50 - 300 nm in length. Instead of forming gels, water dispersions of CNCs have a tendency to form chiral nematic liquid crystals above a critical concentration of ca. 5-10%.

5.2.8 Powdered cellulose

Cellulose is processed into powder by mechanical mulching of fibrous plant material until disintegration into a pulp. This pulp product is typically a white odourless substance made of fibres from plant material. The cellulose is then extracted through chemical means and purified.[15]

5.3 Chemicals

Chemicals are classified as follows by Cepi and include: adhesives, disinfectants and detergents, drilling fluids, paint and dyes, etc. In this study the chemicals are listed in more detail as follows:

5.3.1 Biopolymer

Biopolymers are natural polymers produced by the cells of living organisms. In this survey biopolymers are hemicellulose copolymers with high amounts of functional groups, good barrier properties and low viscosity developed and patented by Ecohelix Ltd. Typical applications include various pulp and paper chemical and cosmetics applications where the polymer´s properties can be utilized. Also, the polymers are highly efficient ingredients in formulations for gas and grease barriers. [16]

[13] https://www.cirfs.org/sustainability/sustainability-elements/man-made-fibres
[14] https://www.exilva.com/blog/microfibrillated-cellulose-or-nanocellulose
[15] https://sites.google.com/a/umn.edu/phar6157s13/home/powdered-cellulose
[16] https://www.ecohelix.se/index.html

5.3.2 Carbon dioxide

Carbon dioxide is a naturally occurring gas, it is also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass, of land use changes and of industrial processes (e.g., cement production).[17] In this survey carbon dioxide is a product refined from biogas production, but in can also be refined from other sources like flue gases. Carbon dioxide is used as a refrigerant, in fire extinguishers, for inflating life rafts and life jackets, blasting coal, foaming rubber and plastics, promoting the growth of plants in greenhouses, immobilizing animals before slaughter, and in carbonated beverages[18].

5.3.3 Dimethyl ether

Dimethyl ether (DME, also known as methoxymethane) is the simplest ether, organic compound with the formula CH_3OCH_3, simplified to C_2H_6O. DME is a colourless volatile poisonous liquid compound used as a solvent, fuel, aerosol, propellant and refrigerant.[19]

5.3.4 Lignosulphonates

Lignosulfonates or sulfonated lignin are water-soluble anionic polyelectrolyte polymers: they are by-products from sulphite pulping. Lignosulfonates have a wide range of uses, such as animal feed, pesticides, surfactants, additives in oil drilling, stabilizers in colloidal suspensions, and as plasticizers in concrete admixtures.

5.3.5 Methanol

Methanol is the simplest alcohol, consisting of a methyl group linked to a hydroxyl group. Raw methanol originating from the kraft cooking process is often used as a support fuel – typically combusted in the recovery boiler or lime kiln. Methanol is usually the last fossil-based chemical in a kraft mill, preventing the establishment of a completely fossil-free mill.[20]

The chemical recovery concept (ANDRITZ process solution: A-Recovery+) for methanol purification uses a mineral oil-based extraction process. Purified methanol can be used as a low-NO_x fuel for combustion in the recovery boiler or lime kiln, or as a support fuel in the sulfuric acid plant. Commercial-grade bio-methanol can also be sold for revenue or used in ClO_2 generation if performed on-site.[21]

5.3.6 Monoethylene glycol

Monoethylene glycol (MEG) is a clear, colourless, virtually odourless, and slightly viscous liquid. It is miscible with water, alcohols, and many organic compounds, and has the formula $C_2H_6O_2$. It is the most important of the commercially available ethylene glycols as it has many industrial applications[22]. It is key raw material for polyesters and antifreeze formulations. Typical uses are for manufacturing bottles, packaging, textiles and de-icing fluids.[23]

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[17] https://sustainability.cepi.org/glossary/
[18] https://www.britannica.com/science/carbon-dioxide
[19] https://pubchem.ncbi.nlm.nih.gov/compound/Dimethyl-ether
[20] https://www.andritz.com/products-en/group/pulp-and-paper/pulp-production/kraft-pulp/a-recovery-plus/methanol-purification
[21] https://www.andritz.com/products-en/group/pulp-and-paper/pulp-production/kraft-pulp/a-recovery-plus/methanol-purification
[22] https://www.solventis.net/products/glycols/mono-ethylene-glycol/
[23] https://www.upmbiochemicals.com/products/glycols/

5.3.7 Monopropylene glycol

Monopropylene glycol (MPG) is a clear, colourless, viscous liquid with a characteristic odour and the formula $C_6H_{14}O_3$. It is fully miscible in water and is also miscible with many organic solvents. This solvency, combined with low toxicity and a low evaporation rate, makes it a chemical which is a very useful reactive intermediate in a range of industries[24]. It carries hygroscopic properties and is miscible in all rations with water, alcohols, esters, ketones and amines.[25] Versatile ingredient for polyester resins and industrial liquids. Typical uses are for composites, antifreeze and detergents.[26]

5.3.8 Sulphuric acid

Sulfuric acid is a colourless, odourless, and viscous oily liquid. It is soluble in water with release of heat. It is corrosive to metals and tissue. It will char wood and most other organic matter on contact but is unlikely to cause a fire. [27]

In chemical pulping the sulfuric acid is produced from sulphur compounds from odorous gases. Sulphuric acid produced at a mill is a further step towards closed chemical circulation and further improves the environmental performance of a kraft pulp mill.

5.3.9 Tall oil products

Tall oil products are based on crude tall oil, which is isolated from acidified skimming of partially concentrated black liquor. They are collected and refined at special plants. The refined tall oil products are natural raw materials for many industrial processes. These bio-based raw materials replace fossil-based ingredients in various everyday products. They are used, for example, in paints, coatings and printing inks. In the future, crude tall oil will be an important ingredient in a variety of products that have antibacterial or cholesterol-lowering properties.[28] Crude tall oil can be also refined in diesel and naphtha via hydrogenation. Naphtha may also be used to replace fossil raw materials in plastics and other chemical industry products.

5.4 Fuels

Fuels are classified as follows by Cepi: bio-cellulosic ethanol, bio-oils, biogas, biodiesel, heating oil, etc.

5.4.1 Biodiesel

Biodiesel is a fuel that contains energy derived from a biological source. For example, rapeseed oil or fish liver oil can be used in place of diesel fuel in modified engines. A commercial application is the use of modified rapeseed oil, which as rapeseed methyl ester (RME) can be used in modified diesel engines and is sometimes named biodiesel.[29] Biodiesel can also be refined from raw tall oil.

[24] https://www.solventis.net/products/glycols/di-propylene-glycol/
[25] https://www.monarchchemicals.co.uk/Information/News-Events/722-/What-is-Mono-Propylene-Glycol
[26] https://www.upmbiochemicals.com/products/glycols/
[27] https://pubchem.ncbi.nlm.nih.gov/compound/Sulfuric-acid#section=Experimental-Properties
[28] https://www.forchem.com/products/
[29] https://www.eea.europa.eu/help/glossary/eea-glossary/biodiesel

5.4.2 Bioethanol

A biofuel produced by the fermentation of plants rich in sugar/starch (e.g. sugar cane, corn).[30] Sugars can also be originated from wood via acid or autohydrolysis.

5.4.3 Biogas

Gas, rich in methane, is produced by the fermentation of animal dung, human sewage or crop residues in an air-tight container. It is used as a fuel to heat stoves, lamps, run small machines and to generate electricity. The residues of biogas production are used as a low-grade organic fertiliser. Biogas fuels do not usually cause any pollution to the atmosphere, and because they come from renewable energy resources they have great potential for future use.[31]

5.4.4 Bio-oil

Bio-oil is typically manufactured via pyrolysis. It is a liquid, typically dark red-brown to almost black depending on the chemical composition of the biomass. Bio-oil is chemically a complex mixture of water, guaiacols, catecols, syringols, vanillins, furancarboxaldehydes, isoeugenol, pyrones, acetic acid, formic acid, and other carboxylic acids. It also contains other major groups of compounds, including hydroxyaldehydes, hydroxyketones, sugars, carboxylic acids, and phenolics.

The bio-oils can be used either as whole bio-oil, fractionated bio-oil, or extracted specific chemicals. The potential applications of the bio-oils include fuels in boilers, engines, and turbines for heat and power generation. Bio-oil can be converted to transportation biofuel by upgrading processes.

5.4.5 Lignin oil

Lignin oil is result of process where solid lignin is converted into a liquid lignin oil using catalytic, energy-efficient process without pressure, below boiling point, without toxic emissions or hazardous residues. Lignin oil is an intermediate product and is delivered to refineries where it is refined into bio-gasoline and biodiesel, in the same way as ordinary fossil crude oil.[32]

5.4.6 Syngas

Syngas, or synthesis gas, is a fuel gas mixture consisting primarily of hydrogen and carbon monoxide. Syngas is usually a product of gasification of biomass and the main application is electricity generation. Syngas is combustible and can be used as a fuel of internal combustion engines.

5.5 Food and Feed

Food and Feed are classified as follows by Cepi: flavourings, preservatives, texturizers and emulsifiers, anti-caking agents and stabilizers, etc.

[30] https://www.eea.europa.eu/help/glossary/eea-glossary/bioethanol
[31] https://www.eea.europa.eu/help/glossary/eea-glossary/biogas
[32] https://renfuel.se/technology/?lang=en

5.5.1 Carboxymethyl cellulose

Carboxymethylcellulose (CMC) or cellulose gum is a synthetic derivative of cellulose, a naturally occurring polysaccharide that is a component of the cell walls of green plants. The base-catalysed reaction between cellulose and chloroacetic acid confers water solubility to the resulting carboxymethylcellulose product that is absent in cellulose.[33]

CMC is used in food under the E number E466 or E469 (when it is enzymatically hydrolysed) as a viscosity modifier or thickener, and to stabilize emulsions in various products including ice cream. It is also a constituent of many non-food products, such as toothpaste, laxatives, diet pills, water-based paints, detergents, textile sizing, reusable heat packs, and various paper products.

5.5.2 Microcrystalline cellulose

MCC is a purified, partly depolymerized cellulose that is manufactured by treating alpha cellulose, obtained from plant materials, with mineral acids. The DP is typically below 400 and no more than 10% of particles are sized less than 5 µm. MCC has an E-code, E460, granted by the European Food Safety Authority. [34]

MCC can be used as anti-caking agent, emulsion stabiliser, replaces fats and oils in low fat foods and reduced fat ice cream, to modify texture (thickens with favourable mouth feel), improves adhesion of sauces, tabletting agent.[35]

5.5.3 Vanillin

Vanillin ($C_8H_8O_3$) is the major flavour constituent of vanilla. It has a wide range of applications in food industry as a flavour agent and in perfumery as an additive. Other applications include antioxidant additive, antifoaming agent, vulcanisation inhibitor and chemical precursor for pharmaceutical and agrochemical industries. There are two commercial types of vanillin: pure vanillin, which is obtained by chemical synthesis, i.e., derived from guaiacol or lignosulphonates and vanilla extract obtained from the pod of tropical Vanilla orchid.[36]

5.6 Pharmaceuticals/Cosmetics

Pharmaceuticals and Cosmetics are classified as follows by Cepi: essential oils, medication, cosmetics, personal hygiene products, etc. The survey did not reveal significant new activity in this area, however, we identified some products [37]such as wound dressing and hydrogel in the field.

[33] https://sites.google.com/a/umn.edu/phar6157s13/home/carboxymethylcellulose-salts
[34] http://www.fao.org/3/w6355e/w6355e0l.htm
[35] https://sites.google.com/a/umn.edu/phar6157s13/home/microcrystalline-cellulose
[36] https://doi.org/10.1016/j.cherd.2009.05.008
[37] https://www.upm.com/

6 Status of biorefineries in EU27 + Norway, Switzerland, UK

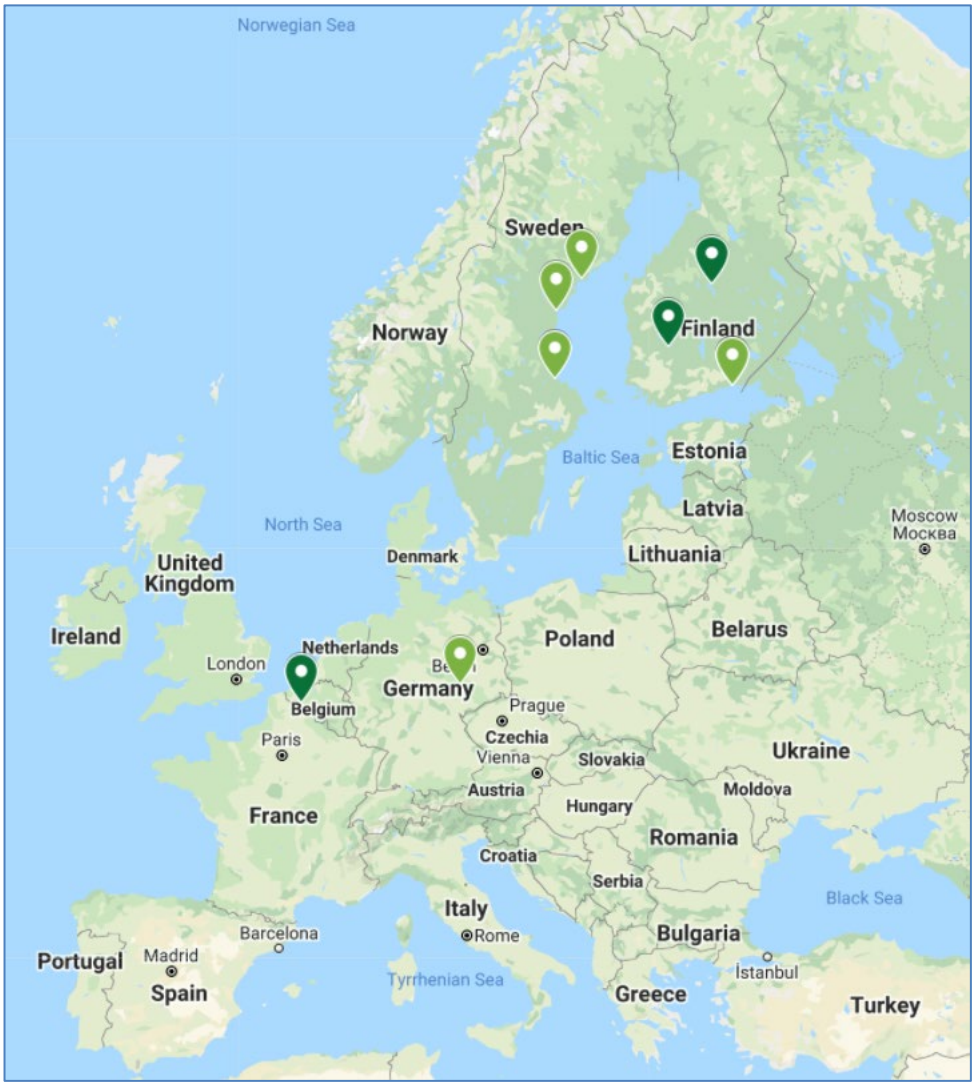
6.1 General

During the study a map was created to show locations of the biorefineries in Europe. The map covers all three biorefinery categories and shows their status – whether an already active mill (i.e. in a commercial production) or a planned mill (i.e. in an investment pipeline) as shown in figs. 4 - 6. The Biorefineries in Europe Map is powered by @NCPartnering.

Figure 4. Map of biorefineries in Europe – CAT 1 (chemical pulping based biorefineries). Dark blue markers indicate an existing plant and light blue a planned facility.

Figure 5. Map of biorefineries in Europe – CAT 2 (paper mill based biorefineries). Dark orange markers indicate an existing plant and light orange a planned facility.

Figure 6. Map of biorefineries in Europe – CAT 3 (Biorefineries based on new processes). Dark green markers indicate an existing plant and light green a planned facility.



6.2 Number of biorefineries in Europe

Most of the biorefineries are located in the EU27 countries (130) and less than ten (9) out of EU27 countries as displayed in table 1. Most of the biorefineries are located in the Cepi member countries (table 2). The biggest number of the biorefineries are in Sweden, Finland, Germany, France and Austria.

The majority of the biorefineries in Europe are based on chemical pulping processes (Category 1). The second largest group are biorefineries mainly using side-streams of existing paper, board and tissue mills (Category 2). There are a few totally new types of biorefineries, which are based on emerging separation methods for wood (Category 3).

Table 1. Summary of the biorefineries in EU27 and Europe in total.

#	Country	1. Biorefineries based on chemical pulping operations to produce various existing or evolving bioproducts		2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bioproducts		3. Other biorefineries using wood as raw material to produce various existing or evolving bioproducts		Total number	
		Active	Planned	Active	Planned	Active	Planned	Active	Planned
1	Austria	10	0	0	1	0	0	10	1
2	Belgium	1	0	1	1	1	0	3	1
3	Bulgaria	2	0	0	0	0	0	2	0
4	Croatia	0	0	0	0	0	0	0	0
5	Cyprus	0	0	0	0	0	0	0	0
6	Czech	2	0	0	0	0	0	2	0
7	**Denmark**	**0**	**0**	**0**	**0**	**0**	**0**	0	0
8	**Estonia**	**2**	**0**	**0**	**0**	**0**	**0**	2	0
9	**Finland**	**25**	**7**	**2**	**0**	**3**	**1**	30	8
10	France	**7**	0	3	0	0	0	10	0
11	Germany	**11**	0	1	0	0	1	12	1
12	Greece	0	0	0	0	0	0	0	0
13	Hungary	**0**	0	0	0	0	0	0	0
14	Ireland	0	0	1	0	0	0	1	0
15	Italy	**1**	0	0	0	0	0	1	0
16	**Latvia**	**0**	**0**	**0**	**0**	**0**	**0**	0	0
17	**Lithuania**	**0**	**0**	**0**	**0**	**0**	**0**	0	0
18	Luxemburg	0	0	0	0	0	0	0	0
19	Malta	0	0	0	0	0	0	0	0
20	Netherlands	**1**	0	3	2	0	0	4	2
21	**Poland**	**4**	**0**	**1**	**0**	**0**	**0**	5	0
22	Portugal	7	0	0	0	0	0	7	0
23	Romania	0	0	0	0	0	0	0	0
24	Slovakia	2	0	0	0	0	0	2	0
25	Slovenia	0	0	0	0	0	0	0	0
26	Spain	4	0	0	0	0	0	4	0
27	**Sweden**	**33**	**8**	**2**	**1**	**0**	**3**	35	12
	EU27 total	**112**	**15**	**14**	**5**	**4**	**5**	**130**	**25**
1	**Norway**	**3**	**2**	**1**	**1**	**0**	**0**	4	3
2	Switzerland	0	0	0	0	0	0	0	0
3	United Kingdom	2	0	3	0	0	0	5	0
	Non-EU27 area	**5**	**2**	**4**	**1**	**0**	**0**	**9**	**3**
	Europe total	**117**	**17**	**18**	**6**	**4**	**5**	**139**	**28**

Table 2. Summary of the biorefineries in Cepi member countries.

#	Country	1. Biorefineries based on chemical pulping operations to produce various existing or evolving bioproducts		2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bioproducts		3. Other biorefineries using wood as raw material to produce various existing or evolving bioproducts		Total number	
		Active	Planned	Active	Planned	Active	Planned	Active	Planned
1	Austria	10	0	0	1	0	0	10	1
2	Belgium	1	0	1	1	1	0	3	1
3	Czech Republic	2	0	0	0	0	0	2	0
4	**Finland**	**25**	**7**	**2**	**0**	**3**	**1**	30	8
5	France	7	0	3	0	0	0	10	0
6	Germany	11	0	1	0	0	1	12	1
7	Hungary	0	0	0	0	0	0	0	0
8	Italy	1	0	0	0	0	0	1	0
9	Netherlands	1	0	3	2	0	0	4	2
10	**Norway**	**3**	**2**	**1**	**1**	**0**	**0**	4	3
11	**Poland**	**4**	**0**	**1**	**0**	**0**	**0**	5	0
12	Portugal	7	0	0	0	0	0	7	0
13	Romania	0	0	0	0	0	0	0	0
14	Slovakia	2	0	0	0	0	0	2	0
15	Slovenia	0	0	0	0	0	0	0	0
16	Spain	4	0	0	0	0	0	4	0
17	**Sweden**	**33**	**8**	**2**	**1**	**0**	**3**	35	12
18	United Kingdom	2	0	3	0	0	0	5	0
	TOTAL	**113**	**17**	**17**	**6**	**4**	**5**	**134**	**28**

The majority of biorefineries in Europe are related to chemical pulping (table 3) accounting for 84% of the active mills totalling 139. Out of planned mills and operations the share of Category 2 and 3 types of biorefineries is getting larger – accounting for about one fifth of all as shown in figures 7 and 8.

Table 3. Division of different type of biorefineries in Europe (EU27+Norway+Switzerland+UK).

		Active	Planned	Total
CAT 1 Based on chemical pulping	#	**117**	**17**	**134**
	%	84	61	80
CAT 2 Based on papermaking	#	**18**	**6**	**24**
	%	13	21	14
CAT 3 Based on new processes	#	**4**	**5**	**9**
	%	3	18	5
		139	**28**	**167**

Figure 7. Share of different type of **active** biorefineries (CAT1 = based on chemical pulping, CAT2 = based on papermaking CAT 3 = based on new type of processes). Total number 139.

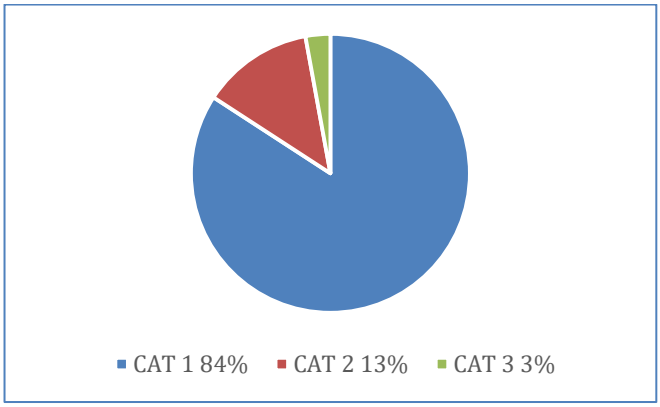
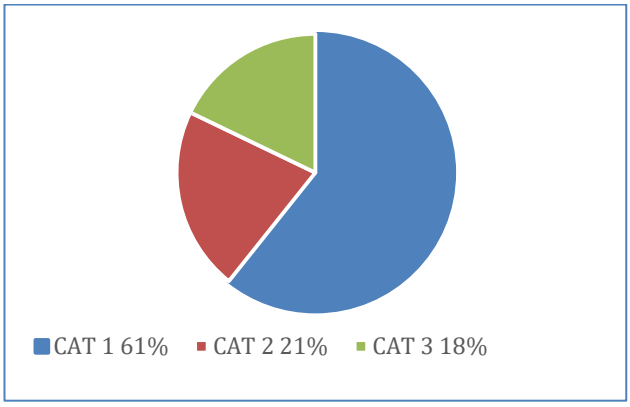


Figure 8. Share of different type of **planned** biorefineries (CAT1 = based on chemical pulping, CAT2 = based on papermaking CAT 3 = based on new type of processes). Total number 28.



Most of the biorefineries are located in the Cepi member countries as displayed in table 4.

Table 4. Division of different type of biorefineries in Cepi member countries.

		Active	Planned	Total
CAT 1 Based on chemical pulping	#	**113**	**17**	**130**
	%	84	61	80
CAT 2 Based on papermaking	#	**17**	**6**	**23**
	%	13	21	14
CAT 3 Based on new processes	#	**4**	**5**	**9**
	%	3	18	6
		134	**28**	**162**

This means that division on different type of biorefineries are same as European level as shown in figures 9 and 10.

Figure 9. Share of different type of active biorefineries (CAT1 = based on chemical pulping, CAT2 = based on papermaking CAT 3 = based on new type of processes). Total number 134.

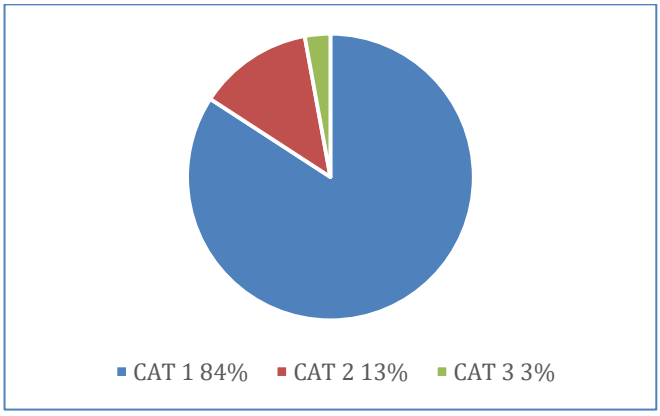
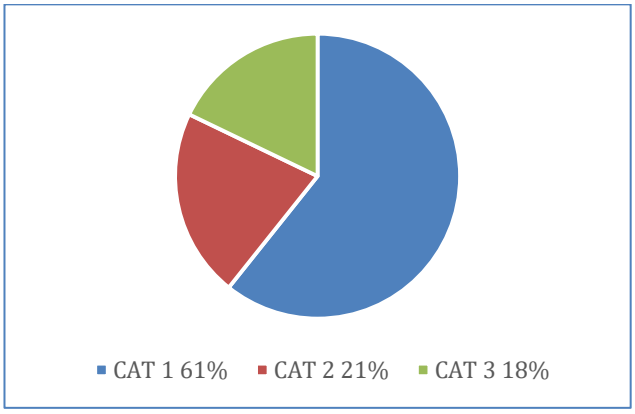


Figure 10. Share of different type of planned biorefineries (CAT1 = based on chemical pulping, CAT2 = based on papermaking CAT 3 = based on new type of processes). Total number 28.



6.3 Value of existing and emerging bio-based products in Europe

According to Cepi, the turnover of the pulp and paper industry in its 18 member countries is €90 billion as per table 5 below. In the study, financial figures were sourced from Cepi and Eurostat and used as a reference. The year 2019 was used to create the overview, as 2020 has been exceptional due the pandemic and figures were not available at the time of writing.

Table 5. Eurostat financial data European pulp and paper industry (Turnover M€ per year).

2019	Cepi	EU-27	EU-27+3	% chge*
Turnover (Million Euros)	90 000	86 247	91 338	-4.3%
Added Value (Million Euros)	20 000	18 947	20 384	-4.8%
Employment	181 504	175 148	186 693	-0.5%

*** Over 2018, Source: Cepi, Eurostat.**

In tables 6 and 7 it can be seen that the majority of the biorefineries (active or planned) are located in the Cepi member countries. Following the study methodology, the turnover generated through the emerging bio-based products which are already actively being produced is €2.65 billion (tables 6 and 7). This corresponds to close to 3% of the turnover of the European pulp and paper industry (total €91.3 billion) or Cepi member countries (€90 billion). It is relatively small today as expected. As stated in the vision for 2050 it is expected that emerging bio-based products will play a bigger role in the future.

Table 6. Turnover of the biorefineries in Europe (EU27+3).

CAT 1 Based on chemical pulping	Turnover, M€	
	M€	% of total
1.1 Active	2 541	95.8
1.2. Planned	1 633	76.9

CAT 2 Based on papermaking	Turnover, M€	
	M€	% of total
2.1 Active	44	1.7
2.2 Planned	2.1	0.1

CAT 3 Based on new processes	Turnover, M€	
	M€	% of total
3.1 Active	66	2.5
3.2 Planned	488	23.0

Biorefineries related EU27+3	Turnover, M€	
	M€	% of total
Active	2 651	100.00
Planned	2 123	100.00

Table 7. Turnover of the biorefineries in Cepi member countries (18 member associations).

CAT 1 Based on chemical pulping	Turnover, M€	
	M€	% of total
1.1 Active	2 540	95.8
1.2 Planned	1 633	76.9

CAT 2 Based on papermaking	Turnover, M€	
	M€	% of total
2.1 Active	44	1.7
2.2 Planned	2.1	0.1

CAT 3 Based on new processes	Turnover, M€	
	M€	% of total
3.1 Active	66	2.5
3.2 Planned	488	23.0

Biorefineries related Cepi	Turnover, M€	
	M€	% of total
Active	2 650	100.00
Planned	2 123	100.00

If we compare the different categories, the largest value in terms of the turnover is related to the CAT 1 type of biorefineries – almost 96% of the total. This is not a surprise considering that chemical pulping is a holistic way to decompose wood elements from each other in an energy efficient way. Despite the process being developed some time ago, chemical pulping still provides a good platform for further refining. It is comparable to the petrochemical industry's oil-refining where the core process was invented over a hundred years ago but is still an efficient way to separate elements of feedstock into various applications. It is assumed that CAT 1 types of biorefineries will continue to play a major role in the future.

In the future, the value (in terms of turnover) of the CAT 3 type of biorefineries will increase. Based on current investment plans, CAT 3 accounts for almost a quarter of all planned biorefineries.

As stated in table 8 there are 28 announced investments for biorefineries/emerging bio-based products corresponding to a total of €6-7 billion investment by 2025. Please note, that not all investment values are publicly available.

NOTE 1: These biorefineries can produce also traditional bio-based products but as per definition in this study a chemical pulp mill can be a platform for a potential producer of emerging bio-based products.

NOTE 2: When we are evaluating value of the bio-based products, <u>only</u> emerging bio-based products are reckoned into the calculations. i.e. in cases where a pulp mill is producing traditional products it is included in the numbers of the biorefineries, but it is only included in the value calculations when producing emerging bio-based products.

Table 8. Announced biorefinery/bio-based product investment plans 2020 – 2025.

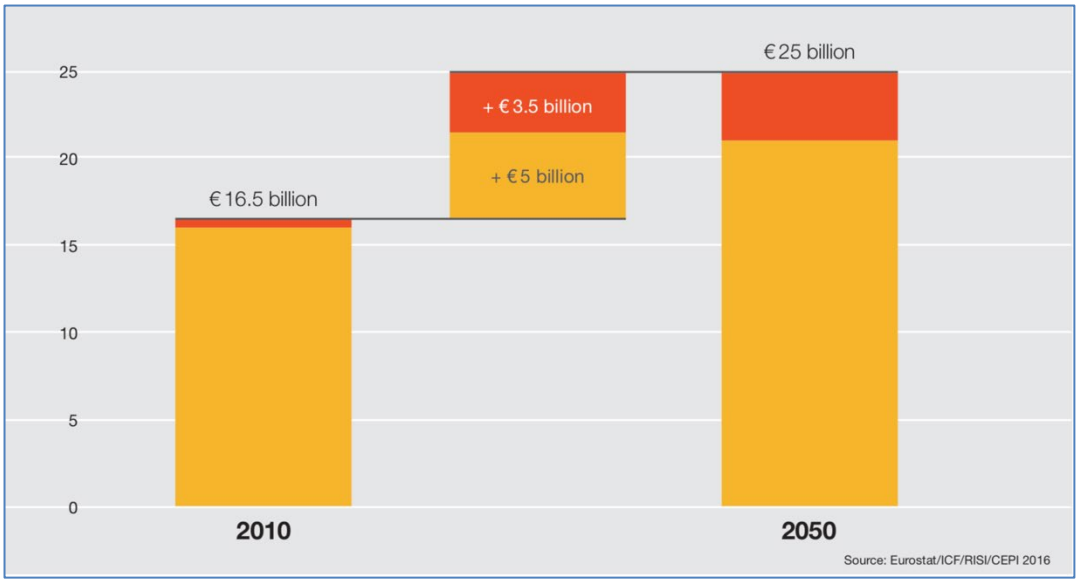
					Start up	
		Unit	**Location**	**Produts**	**Year**	**Note**
Cat1	**1**	Metsä Fibre	Kemi, Finland	Bio-based products	2022	Potential biorefinery platform
	2	KaiCell Fibers	Paltamo, Finland	Bio-based products	2024	Potential biorefinery platform
	3	Boreal Bioref	Kemijärvi, Finland	Bio-based products	2023	Potential biorefinery platform
	4	Fintoil Oy	Hamina, Finland	Biofuels chemicals for food and pharmaceutical industries	2022	
	5	Finnpulp	Kuopio, Finland	Bio-based products	2024	Potential biorefinery platform
	6	UPM-Kymmene Biofuels	Kotka, Finland	Biofuels	2022	
	7	Stora Enso	Finland or Sweden	Kraft lignin	2025	No information of the place
	8	Borregaard Ltd	Sarpsborg, Norway	Biogas	2021	
	9	MMK FollaCell	Follafoss, Norway	Biogas	2022	
	10	SunPine	Piteå, Sweden	Crude tall diesel	2022	
	11	Preem	Gotenburg, Sweden	HVO diesel	2020	
	12	Renfuel	Renfuel, Stocholm	Lignin oil	2021	
	13	ST1 and SCA	Gotenburg, Sweden	HVO diesel, jet fuel, and naphtha	2022	
	14	Preem	Gotenburg, Sweden	Crude tall diesel, fats, veg. oils	2024	
	15	SunCarbon	Lund, Sweden	Lignin oil	N/A	
	16	RenCom	Knivsta, Sweden	RENOL® , biobased plastics (degradable)	2022	
	17	Stora Enso	Fors, Sweden	Cellufoam™	N/A	
Cat2	**1**	Norske SkogM Bruck	Styria, Austria	Biogas	2023	
	2	Stora Enso Langerbrugge	Langerbrugge, Belgium	Biogas	2021	
	3	Essity Operations Cuijk bv	Cuijik, NL	Biogas	2025	
	4	Mayr-Melnhof Eerbeek BV	Eerbeek, NL	Fibrillated Cellulose	N.A.	
	5	Norske Skog	Saugbrugs, Norway	Composites	N/A	
	6	Stora Enso Nymolla Paper mill	Nymolla, Sweden	Biogas	2020	
Cat3	**1**	UPM Leuna	Leuna, Germany	Bio chemicals	2022	
	2	BioA Oy	Kotka, Finland	Fertiliser	2020	
	3	Pyrocell	Gävle, Sweden	Bio-oil	2021	
	4	SCA Biorefinery Östrand AB	Timrå, Sweden	Hydrocarbons (petrol, diesel, jet)	2022	
	5	Ecohelix	Domsjö, Sweden	Polymers for barrier materials	2020	

In the case of all indicated investment plans materialising, turnover of emerging bio-based products will increase to reach €4.8 billion by 2025 (in the table 6 and 7: €2.7 billion + €2.1 billion), which will provide a relative value of emerging bio-based products at 4-5% in comparison to European PPI turnover. This is estimate – where value of the European PPI turnover would be €95 Billion (today €91 billion)

In terms of added value, typically for the pulp and paper industry the added value accounts for 22% of the annual turnover (table 5: €20 billion / €90 billion ≈ 22%, which has been typical during the recent years).

In absolute terms added-value has increased steadily since 2011 (€16.5 billion), when vision 2050 was launched. According to the 2050 vision added value is expected to grow by 50% reaching €25 billion, figure 11.

Figure 11. Added-value growth projection for the European forest fibre and paper industry by 2050 (in billion €).



If we have a look at added value for the emerging bio-based products it can be evaluated as follows. Currently emerging bio-based products generate €2.65 billion turnover. Companies generally do not publicly disclose the added value of these products. We can simulate added value by different scenarios:

a) Added value as industry average - i.e. 22%
b) Attractive added value creation - i.e. 30%
c) Enhanced added value creation - i.e. 35%

Some indications are already currently implying that added value creation is higher for the emerging bio-based products; otherwise it would not make sense to seek out these new product areas.

In the projections we have annual growth simulated to be 2% and 5%. These are reasonable when taking into account that there are several announced investment plans. These investment plans account for an additional turnover over €2 billion (in tables 6 and 7). This alone would mean (by using the industry average added value ≈22%) an additional added value of €450 million by 2025 – this will correspond a growth rate of 5% per annum.

Also, companies are striving for better margins. It can be projected that added value for emerging bio-based products is more than the industry average (22%). Our projection uses 30% added value.

When combining the assumptions above, our forecast for added value will follow the black line in figure 12, which indicates that added value by 2050 would be €3.500 billion for the emerging bio-based products.

Figure 12. Added value of emerging bio-based products in different scenarios (M€). Growth rate 5% per annum.

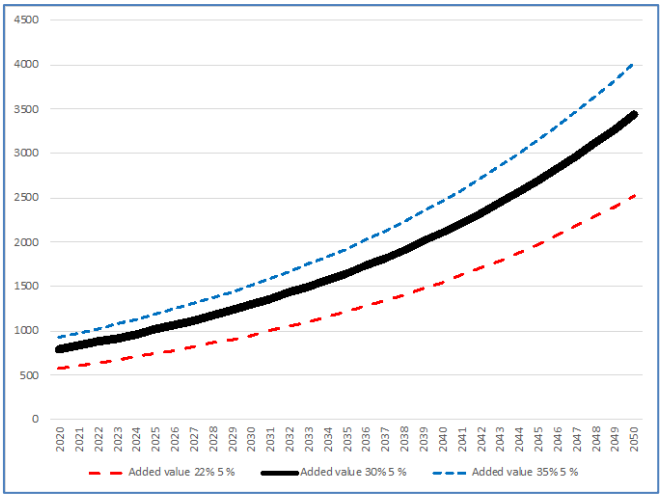
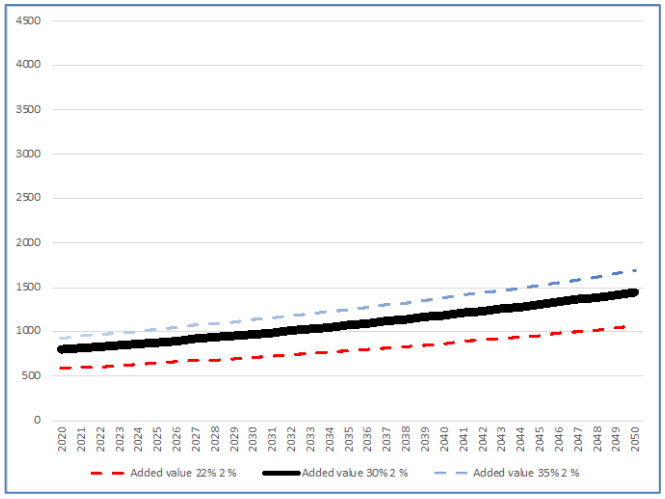


Figure 13. Added value of emerging bio-based products in different scenarios (M€). Growth rate 2% per annum.



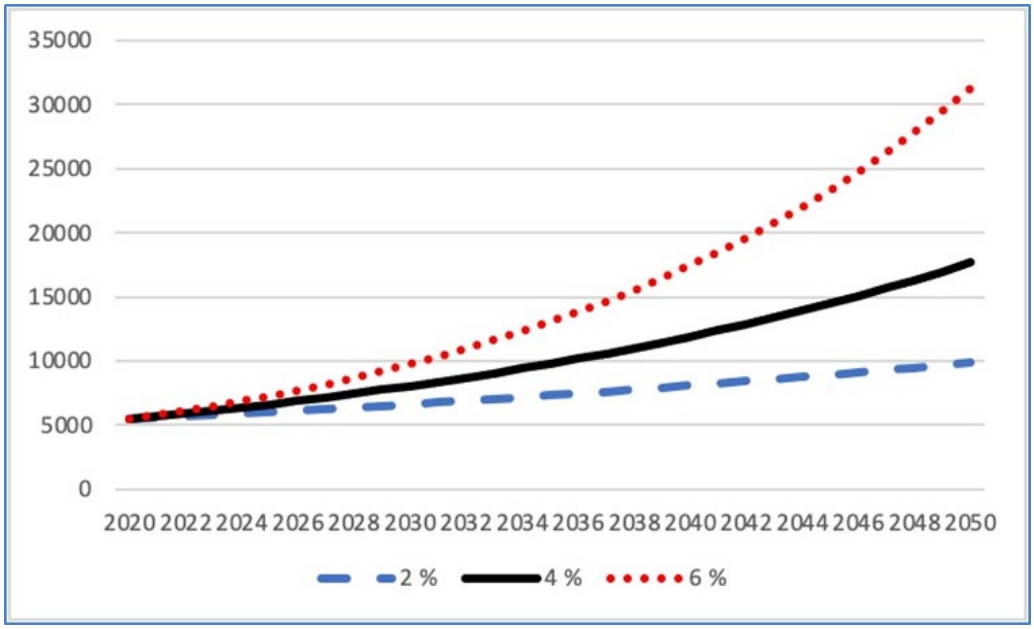
Total employment in the pulp and paper industries in Europe (EU-27+3) is 186 693 and in Cepi countries 181 504 (table 5). In many cases bio-based products are produced by existing operations and increased employment in these areas is generally not announced. Thus, in the study, we are using same share as the value of the business (3% at the moment) to evaluate the employment rate. The emerging bio-based sector employs 5 445 people in Cepi countries as per table 9.

We have simulated various growth rates for the employment (2%, 4%, 6%) in the European pulp and paper industry until 2050. As the industry is in transition and we are seeing more R&D programs and investments related to emerging bio-based products we are expecting employment rate to increase by 4% per annum, which will mean the sector would employ 18 000 people by 2025 as per figure 14. This is also well in line with the expectation that the emerging bio-based sector's added value growth is 5% per annum. When taking into account the improvement in productivity, we can predict that employment will increase, but at a lower rate i.e. 4%.

Table 9. Employment of the emerging bio-based sector.

2020	**Cepi**	**EU-27**	**EU-27+3**
Employment	5 445	5 254	5 600

Figure 14. Development of the employment for emerging bio-based products.



6.4 Status on country level

Country level data are collected in a separate excel sheet containing the following information:

- Mill - company information
- Website
- Location
- Ownership
- Management
- Feedstock
- Major process
- Products
- Capacity (fibres, chemicals and energy)
- New investments (Scope, TRL, Value and start-up year)
- Turnover (value and jobs)
- Increment (value)
- Notes

The Database has been provided to Cepi.

6.4.1 Austria

Austria has a dedicated bioeconomy strategy at the national level.[38]

There are nine pulp mills and 21 paper mills in operation.[39]

The national association, Austropapier (https://en.austropapier.at), is a member of Cepi.

Major institutes related to wood-based bioproducts are as follows:

- Graz University of Technology, https://www.tugraz.at/en/home/
- Ausbildungszentrum der Österreichischen Papierindustrie, http://www.papiermacherschule.at
- Holzforschung Austria, https://www.holzforschung.at/
- University of Natural Ressources and Life Sciences, Vienna, https://boku.ac.at/en/
    - Institute of Chemistry of Renewable Resources, https://boku.ac.at/en/chemie/wpf
    - Institute of Environmental Biotechnology, https://boku.ac.at/en/ifa-tulln/institut-fuer-umweltbiotechnologie/staff

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
    - Zellstoff Pöls AG, https://www.zellstoff-poels.at
    - Mondi Neusiedler GmbH, https://www.mondigroup.com/en/home/
    - Mondi Frantschach GmbH, https://www.mondigroup.com/en/home/
    - Sappi Gratkorn Mill, https://www.sappi.com/gratkorn-mill
    - Lenzing AG, https://www.lenzing.com/
    - AustroCel Hallein GmbH, www.austrocel.com
    - Smurfit Kappa Nettingsdorf, www.smurfitkappa.at
    - Poneder, http://www.poneder.at/welcome.html
    - Lenzing Fibers GmbH, https://www.lenzing.com/
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active – not identified
- Planned
    - Norske Skog Bruck GmbH, https://www.norskeskog.com/Business-units/Europe/Norske-Skog-Bruck

[38] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[39] CEPI annual statistics 2018.

6.4.2 Belgium

Belgium does not have a dedicated bioeconomy strategy at the national level, but it has other policy initiatives dedicated to the bioeconomy.[40]

There are two pulp mills (one chemical / one mechanical) and seven paper mills in operation.[41]

The national pulp and paper association, Cobelpa (http://www.cobelpa.be), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- University of Antwerp, https://www.uantwerpen.be/en/
- Ghent University, https://www.ugent.be/en
- KU Leuven, https://www.kuleuven.be/english/
- VITO, https://vito.be/en
- Valbiom, http://www.valbiom.be/

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Burgo Ardennes, https://www.burgo.com/en/group/paper-mills/burgo-ardennes
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - Sappi Lanaken, https://www.sappi.com/lanaken-mill
- Planned
  - Stora Enso Langerbrugge, https://www.storaenso.com/en/about-stora-enso/stora-enso-locations/langerbrugge-mill

CAT3. Other biorefineries using wood as raw material to produce various existing or evolving bio-based products

- Active
  - Beologic, https://www.beologic.com/beograde,
- Planned – not identified

6.4.3 Bulgaria

Bulgaria does not have a dedicated bioeconomy strategy at the national level, but it has other comprehensive separate national strategies for agriculture, forestry, and biodiversity, which are under revision to be integrated into a national bioeconomy strategy.[42]

[40] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[41] CEPI annual statistics 2018

There are two chemical pulp mills and over 10 paper and board mills in operation.

Bulgaria does not have a national pulp and paper association, however it has a branch in the chamber of commerce (Branch Chamber of Pulp and Paper Industry, www.bappi.org). It is not a member of Cepi.

The major institutes related to wood bio products are as follows:

- the Bulgarian National Institute for Pulp and Paper, http://ppibg.com/en/home-3-3/

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Svilocell Eood / Svilosa AD, Svishtov, www.svilosa.bg
  - Mondi, Stambolijski, https://www.mondigroup.com/en/about-mondi/where-we-operate/europe/bulgaria/mondi-stambolijski/
- Planned – not identified

6.4.4 Croatia

Croatia has a dedicated national bioeconomy strategy under development.[43]

No biorefineries belonging to the categories in the study have been identified.

6.4.5 Cyprus

Cyprus has no dedicated national bioeconomy strategy, but there are other related strategies at the national level.[44]

No biorefineries belonging to the categories in the study have been identified.

6.4.6 Czech Republic

In Czech Republic, a dedicated bioeconomy strategy at the national level is under development.[45]

There are two pulp mills (one chemical / one mechanical) and 14 paper mills in operation.[46]

The national association, the Association of the Pulp and Paper Industry (ACPP, http://www.acpp.cz/en), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- University of Pardubice, https://www.upce.cz/en

[42] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[43] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[44] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[45] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[46] CEPI annual statistics 2018

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Lenzing Paskow, https://www.lenzing.com/lenzing-group/locations/lenzing-biocel-paskov
  - Mondi Steti, https://www.mondigroup.com/en/about-mondi/where-we-operate/our-locations/europe/czech-republic/mondi-štět%C3%AD/
- Planned – not identified

6.4.7 Denmark

Denmark does not have a dedicated bioeconomy strategy at the national level. They have other policy initiatives dedicated to the bioeconomy. [47]

There are no pulp mills but there are nine paper and board mills in operation.[48]

The major association in the industry is the Danish Paper, Board and Pulp Makers Association. It is not a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Aalborg University, https://www.en.aau.dk/
- Aarhus University, https://international.au.dk/
- Copenhagen University, https://www.ku.dk/english/
- Technical University of Denmark, https://www.dtu.dk/english
- Danish Technological Institute, https://www.dtu.dk/english

6.4.8 Estonia

Estonia is still working on its own bioeconomy strategy. They also have other policy initiatives dedicated to the bioeconomy.[49]

There are two pulp mills (one kraft mill and one BCTMP mill) and few paper and board mills in operation.

The major associations in this field:

- Association of Estonian Printing and Packaging Industry (AEPPI), www.etpl.ee
- Estonian Forest and Wood Industries Association, https://estoniantimber.ee/

The major institutes related to wood-based bioproducts are as follows:

- Estonian University of Life Sciences, https://www.emu.ee/en/
- Tallinn University of Applied Sciences, https://www.tktk.ee/en
- University of Tartu, https://www.ut.ee/en

[47] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[48] https://www.statista.com/statistics/992081/production-volume-of-paper-and-paperboard-in-denmark/
[49] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Horizon Pulp and Paper, Kehra, https://www.horizon.ee/
  - Estonian Cell, Kunda, https://www.estoniancell.ee/en/
- Planned – not identified

6.4.9 Finland

Finland has a dedicated bioeconomy strategy at the national level[50,51].

There are 14 chemical pulp mills and 30 paper and board mills in operation.[52]

The major association in the industry, Finnish Forest Industries Federation (FFIF, https://www.forestindustries.fi/), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Aalto University, https://www.aalto.fi/en
- Åbo Akademi University, https://www.abo.fi/en/
- LUT University, https://www.lut.fi/web/en/
- Natural Resources Institute, https://www.luke.fi/en/
- University of Oulu, https://www.oulu.fi/university/
- VTT, https://www.vttresearch.com/en
- University of Helsinki, https://www.helsinki.fi/en

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Metsä Fibre, Äänekoski, https://www.metsafibre.com/en
  - Metsä Fibre, Kemi
  - Metsä Fibre, Rauma
  - Metsä Fibre, Joutseno
  - UPM, Pietarsaari, https://www.upm.com/
  - UPM Kaukas, Lappeenranta
  - UPM, Kymi
  - Stora Enso, Oulu, https://www.storaenso.com/
  - Stora Enso, Varkaus
  - Stora Enso Kaukopää, Imatra
  - Stora Enso Tainionkoski, Imatra

[50] https://www.bioeconomy.fi/, Sustainable growth from bioeconomy - THE FINNISH BIOECONOMY STRATEGY
[51] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[52] CEPI Annual Statistics 2018

  - Stora Enso, Veitsiluoto
  - Stora Enso, Uimaharju
  - Stora Enso, Sunila, Kotka
  - Stora Enso, Heinola
  - Kotkamills, Kotka, https://kotkamills.com/
  - Mondi Powerflute, Kuopio, https://www.mondigroup.com/en/home/
  - UPM-Kymmene Biofuels, Lappeenranta, https://www.upmbiofuels.com
  - Kraton Ltd, Oulu, https://www.kraton.com/
  - Forchem Ltd, Rauma, https://www.forchem.com
  - Joutseno pulp mill, Joutseno, https://www.metsaboard.com
  - Kaskinen pulp mill, Kaskinen, https://www.metsaboard.com
  - Nouryon Ltd, Äänekoski, https://www.nouryon.com/
  - MetsäSpring Ltd, Äänekoski, https://metsaspring.com/
- Planned
  - Metsä Fibre Ltd, Kemi, https://www.metsafibre.com/en
  - KaiCell Ltd, Paltamo, http://kaicellfibers.fi/
  - Boreal Bioref, Kemijärvi, http://www.borealbioref.fi/en/
  - Fintoil Ltd, Kotka, https://fintoil.com/
  - Finnpulp Ltd, Kuopio, https://www.finnpulp.fi/en/
  - UPM-Kymmene Biofuels Ltd, Kotka, https://www.upmbiofuels.com
  - Stora Enso, Sunila, Kotka, https://www.storaenso.com/

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - UPM Biocomposites Ltd, Lahti, https://www.upmprofi.com/composite-manufacturer
  - Stora Enso, Anjalankoski, https://www.storaenso.com/
- Planned - not identified

CAT3. Other biorefineries using wood as raw material to produce various existing or evolving bio-based products

- Active
  - BioA Ltd, Kotka, https://bioa.fi/
  - Ecolan Ltd, Viitasaari, https://www.ecolan.fi/en/
  - Ecolan Ltd, Nokia, https://www.ecolan.fi/en/
- Planned
  - BioA Ltd, Kotka, https://bioa.fi/

6.4.10 France

France has a dedicated bioeconomy strategy at the national level.[53]

There are six chemical pulp mills and 80 paper and board mills in operation.[54]

[53] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

The major association in the field is the Association of French Paper Industries (COPACEL, http://www.copacel.fr/en) which is a member of Cepi.

Major institutes related to wood-based bioproducts are as follows:

- Centre Technique du Papier (CTP), http://www.webctp.com/gb/default.cfm
- Institut Technologique FCBA, https://www.fcba.fr/en
- Grenoble-Inp, https://www.grenoble-inp.fr/en/grenoble-inp
- INRA (French National Institute for Agricultural and environmental Research), https://www.inrae.fr/en
- AgroParisTech, http://www2.agroparistech.fr/Welcome-to-AgroParisTech
- L'Université de Reims Champagne-Ardenne, https://www.univ-reims.eu/
- L'Ecole de l'Innovation de la Transition, http://ensaia.univ-lorraine.fr/en
- SFR Condorcet, http://www.sfr-condorcet.fr/?lang=en
- CEA, http://www.cea.fr/english

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
    - Rayonier Advanced Materials, https://rayonieram.com/paper-and-pulp/high-yield-pulp/
    - Reyonier Advanced Materials, Avebene Unit, https://rayonieram.com/high-purity-cellulose/
    - Smurfit Kappa Cellulose du Pin, https://www.smurfitkappa.com/locations
    - Gascogne Papier, https://www.gascognepapier.com/en/
    - IP Saillat sur Vienne, http://www.internationalpaper.com/company/regions/
    - Fibre Exelence Saint Gaudens SAS, http://www.fibre-excellence.fr/fibre-excellence-st-gaudens.php
    - Fibre Exelence Tarascon, http://www.fibre-excellence.fr/fibre-excellence-tarascon.php,
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
    - Norske Skog Golbey, https://norskeskog-golbey.com
    - Blue Paper SAS Strasbourg, http://www.bluepaper.eu/
    - Cartonneries de Gondardennes CGW, http://www.cartonneries-gondardennes.com/en
- Planned – not identified

6.4.11 Germany

Germany has a dedicated bioeconomy strategy at the national level. It has also been revised recently.[55]

There are 15 pulp mills (both chemical and mechanical) and 155 paper mills in operation.[56]

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[54] CEPI Annual Statistics 2018
[55] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

The German Pulp and Paper Association (VDP, https://www.vdp-online.de/en/) is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Uni Hamburg, Thynen-Institut, https://www.thuenen.de/en/hf/
- CBP Leuna (FhG IMG Stuttgart), https://www.cbp.fraunhofer.de/en/About_us/cbp-branch-of-fraunhofer-igb.html
- FhG WKI Braunschweig, https://www.wki.fraunhofer.de
- Uni Göttingen, Inst. für Holztechnologie, https://uni-goettingen.de/en/131929.html
- Papiertechnische Stiftung Heidenau, https://www.ptspaper.com
- Uni München, Bereich Straubing/FhG IMG Stuttgart, https://www.tum.de/en/about-tum/our-university/locations/campus-straubing/
- ZBM TH Rosenheim, https://www.th-rosenheim.de/en/research-development/cbm-center-for-bio-based-materials/
- FhG IPA Potsdam, https://www.iap.fraunhofer.de/de/fraunhofer-iap.html
- Institute of paper technology, https://ivp.org/en

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Merzer – Rosenthal, https://mercerint.com/operations/rosenthal
  - Merzel – Stendal, https://mercerint.com/operations/stendal
  - Sappi – Ehingen, https://www.sappi.com/fi/ehingen-mill
  - Sappi Stockstadt, https://www.sappi.com/fi/stockstadt-mill
  - Sappi Alfeld, https://www.sappi.com/alfeld-mill
  - Kelheim, http://kelheim-fibres.com/en/
  - Celanese, http://www.celanese.de/About-Us.aspx
  - LignoTech Werk Karlsruhe, https://www.borregaard.com/About-us/Contact-us/Borregaard-worldwide/Borregaard-Deutschland-GmbH-S-P
  - Kraton, https://kraton.com/company/locations.php
  - Cordenka, https://www.cordenka.com/en/cordenka/
  - Enka, http://www.enka.de/index_en.php
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - UPM Profi, Bruchsal, https://www.upmprofi.com
- Planned – not identified

CAT3. Other biorefineries using wood as raw material to produce various existing or evolving bio-based products

[56] CEPI annual statistics 2018

- Active – not identified
- Planned
    - UPM – Leuna, https://www.upmbiochemicals.com/biorefinery/

6.4.12 Greece

Greece has no dedicated national bioeconomy strategy, but there are other related strategies on the national level.[57]

No biorefineries belonging to the categories in the study have been identified.

6.4.13 Hungary

Hungary is in the process of producing a national bioeconomy strategy.[58]

Hungary does not have any chemical pulp mills in operation, but over 10 paper and board mills producing paper and paperboard.

The Hungarian Association of pulp and paper industry Fedprint (http://www.fedprint.hu) is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Hungarian Institute for Wood and Paper Technology, http://nrrc.nyme.hu/en/institute-of-wood-and-paper-technology/

No biorefineries belonging to the categories in the study have been identified.

6.4.14 Ireland

Ireland has a dedicated biostrategy at national level.[59]

Ireland has no chemical pulp mills in operation and no paper mills.

The major institutes related to wood-based bioproduct research are as follows:

- BiOrbic, https://biorbic.com/

No biorefineries belonging to the categories in the study have been identified.

6.4.15 Italy

Italy has a dedicated national bioeconomy strategy.[60]

[57] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[58] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[59] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

There are four pulp mills (two mechanical, one semi-chemical and one chemical) and 119 paper mills in operation.[61]

The national pulp and paper association Assocarta (http://www.assocarta.it/en/) is a member of Cepi.

The major institutes related to wood-based bio-based products are as follows:

- Alma Mater Studiorum - Università di Bologna, https://www.unibo.it/it
- Polito - Polytechnic of Torino, https://www.polito.it/?lang=en

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Burgo Tolmezzo, https://www.burgo.com/en/group/paper-mills/tolmezzo
- Planned – not identified

6.4.16 Latvia

Latvia has a dedicated bioeconomy strategy at the national level.[62]

There are no pulp mills but there are a few paper and board mills in operation.

The major associations in the field:

- Latvian Printers' Association, www.lpua.lv
- Packaging Association of Latvia, www.packaging.lv
- Latvian Biomass Association, http://latbio.lv/home/

The major institutes related to wood-based bioproducts are as follows:

- Latvia University of Life Sciences and Technologies, https://www.llu.lv/en
- Riga Technical University, https://www.rtu.lv/en

No biorefineries belonging to the categories in the study have been identified.

6.4.17 Lithuania

Lithuania does not have a dedicated bioeconomy strategy at the national level however it is under development.[63]

There are no pulp mills but there are a few paper and board mills in operation.

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[60] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[61] CEPI Annual Statistics 2018
[62] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[63] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

The major associations in the field:

- Association of Lithuanian Printing Industries (LISPA), https://lispa.net/
- Lithuanian Biomass Energy Association, http://www.biokuras.lt/en
- Lithuanian Biotechnology Association, http://lbta.lt/en/lithuanian-biotechnology-associasion

The major institutes related to wood-based bioproducts are as follows:

- Kaunas University of Technology, https://en.ktu.edu/
- Lithuanian Research Centre for Agriculture and Forestry, https://www.lammc.lt/en
- Vilnius Gediminas Technical University, https://www.vgtu.lt/
- Vilnius University Life Sciences Center, https://www.gmc.vu.lt/en/
- Vytautas Magnus University, https://www.vdu.lt/en/

No biorefineries belonging to the categories in the study have been identified.

6.4.18 Luxemburg

Luxemburg has no dedicated national bioeconomy strategy, but there are other related strategies on the national level.[64]

No biorefineries belonging to the categories in the study have been identified.

6.4.19 Malta

Malta has no dedicated national bioeconomy strategy, but there are other related strategies on the national level.[65]

No biorefineries belonging to the categories in the study have been identified.

6.4.20 Netherlands

The Netherlands has a dedicated bioeconomy strategy at the national level.[66]

The Netherlands does not have any chemical pulp mills but there are over 20 paper and board mills in operation.

The national association, the Royal VNP (Vereniging van Nederlandse Papier- en kartonfabrieken www.vnp.nl), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Wageningen University and Research FBR (Food and Biobased Research), https://www.wur.nl/en/Research-Results/Research-Institutes/food-biobased-research.htm

[64] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[65] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[66] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

- University of Groningen, https://www.rug.nl/?lang=en
- Utrecht University, https://www.uu.nl/en
- University of Twente, https://www.utwente.nl/en/
- Eindhoven University of Technology, https://www.tue.nl/en/

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Sappi Limited, Pilot-scale plant for Cellulose NanoFibrils production, https://www.sappi.com/nanocellulose
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - DS Smith Paper De Hoop Eerbeek, https://www.dssmith.com/paper/about/paper-mills/de-hoop-nl
  - Eska B.V., https://eska.com
- Planned
  - Essity Operations Cuijk B.V., https://www.essity.com
  - Mayr-Melnhof Eerbeek B.V., https://www.mm-karton.com/en/company/mills/eerbeek/#about-the-mill-59d7772ec2493222444795

6.4.21 Norway

Norway has a dedicated bioeconomy strategy at the national level.[67,68]

There are two pulp mills (one sulphite mill and one BCTMP mill) and in six[69] paper and board mills in operation.

The major associations in the field:

- The Norwegian Pulp and Paper Association (TFB), https://www.norskindustri.no/
- The Technical Association of the Norwegian Pulp and Paper Industry (TPF), https://ptf.no/

The major institutes related to wood-based bioproducts are as follows:

- Norwegian University of Life Sciences, www.nmbu.no
- Norwegian Institute of Bioeconomy Research, https://www.nibio.no/en
- Norwegian University of Science and Technology (NTNU), www.ntnu.edu
- RISE-PFI, https://www.rise-pfi.no/

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

[67] https://www.regjeringen.no/en/dokumenter/regjeringens-biookonomistrategi-kjente-ressurser--uante-muligheter/id2521997/
[68] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[69] CEPI Annual Statistics 2018

- Active
  - Borregaard, Sarpsborg, https://www.borregaard.com/
  - MMK FollaCell, Follafoss, https://www.mm-karton.com/en/company/mills/follacell/
  - Norske Skog, Saugbrugs, https://www.norskeskog.com/
- Planned
  - Borregaard, Sarpsborg, https://www.borregaard.com/
  - MMK FollaCell, Follafoss, https://www.mm-karton.com/en/company/mills/follacell/

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - Norske Skog, Skogn, https://www.norskeskog.com/
- Planned
  - Norske Skog, Saugbrugs, https://www.norskeskog.com/

6.4.22 Poland

Poland does not have a dedicated bioeconomy strategy at the national level however it is under development.[70]

There are three pulp mills and 52 paper and board mills in operation.[71]

The major association in the industry, Association of Polish Papermakers (SPP, http://www.spp.pl/home.php), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Politechnika Łódzka Centrumm Papiernictwa i Poligrafii, https://inpap.p.lodz.pl/en/
- Polish Packaging research and Development Centre – COBRO, http://www.cobro.org.pl/english/
- Lodz University of Technology, https://www.p.lodz.pl/en/welcome-lodz-university-technology

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - KWIDZYN SP. Z O.O., Kwidzyn, www.ipaper.com.pl
  - STORA ENSO POLAND S.A., Ostrołęka, www.storaenso.com
  - Mondi Świecie S.A, Świecie, www.mondigroup.com/
  - ENKA GmbH & Co. KG, http://www.enka.de/index_en.php
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

[70] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[71] CEPI Annual Statistics 2018

- Active
  - STORA ENSO POLAND S.A., Ostrołęka, www.storaenso.com
- Planned – not identified

6.4.23 Portugal

In Portugal, a dedicated bioeconomy strategy at the national level is under development.[72] There is an official National Plan for the Promotion of Biorefineries available (in Portuguese only).[73]

In Portugal, there are seven pulp mills and over 25 paper and board mills in operation.[74]

The national pulp and paper association Associação da Indústria Papeleira (Celpa, http://www.celpa.pt/en/) is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Forest and Paper institute, http://raiz-iifp.pt/en/
- Association BLC3 - Technology and Innovation Campus, http://blc3.pt/about.php?lang=en#
- Centro da Biomassa Para a Energia, https://centrodabiomassa.pt
- Collaborative Laboratory (CoLAB) for Research & Innovation Biorefineries (BIOREF), https://www.bioref-colab.pt/pt
- The Bioenergy and Biorefineries Unit, https://www.lneg.pt/en/unit/bioenergy-unit/

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Altri – Celbi, http://www.altri.pt/en/what-we-do/pulp/celbi
  - Altri – Celtejo, http://www.altri.pt/en/what-we-do/pulp/celtejo
  - Altri – Caima, http://www.altri.pt/en/what-we-do/pulp/caima
  - Navigator – Setúbal, http://en.thenavigatorcompany.com/Institutional/Our-activity/Setubal
  - Navigator - Figueira da Foz, http://en.thenavigatorcompany.com/Institutional/Our-activity/Figueira-da-Foz
  - Navigator – Cacia, http://www.thenavigatorcompany.com/Institucional/A-Nossa-Actividade/Cacia
  - DS Smith - Viana do Castelo, https://www.dssmith.com/paper/about/paper-mills/viana-pt
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active

[72] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[73] https://dre.pt/home/-/dre/114133883/details/maximized
[74] CEPI annual statistics 2018

- Renova – Torres Novas, https://www.myrenova.com/?utm_source=wellbeing&utm_medium=web&utm_campaign=redirect
- Planned – not identified

6.4.24 Romania

Romania does not have a bioeconomy strategy at the national level.[75]

Romania does not have any pulp mills in operation. There are more than 20 paper and paperboard mills in the country.

The national pulp and paper association, the Patronising Association of Pulp and Paper Industry (ROMPAP), is a member of Cepi.

Major institutes related to wood-based bioproducts are as follows:

- Research Institute Ceprohart SA, http://www.ceprohart.ro

No biorefineries belonging to the categories in the study have been identified.

6.4.25 Slovakia

In Slovakia, a dedicated bioeconomy strategy at the national level is under development.[76]

There are two pulp mills and five paper and board mills in operation.[77]

The national pulp and paper association, the Pulp and Paper Industry Federation of Slovak Republic (ZCPP, http://www.paper.sk/zcpp.php?lang=uk), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Pulp and Paper Research Institute, a.s., http://www.vupc.sk/index.php/en
- Slovak Technical University, https://www.stuba.sk/english.html?page_id=132

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Mondi SCP, https://www.mondigroup.com/en/about-mondi/where-we-operate/our-locations/europe/slovakia/mondi-scp/
  - Bukocell a.s., https://bukoza.sk/en/products/pulp
- Planned – not identified

[75] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[76] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[77] CEPI annual statistics 2018

6.4.26 Slovenia

Slovenia does not have a dedicated national bioeconomy strategy, but there are other policy initiatives dedicated to the bioeconomy.[78]

The national association, the Paper and Paper Converting Industry Association – Chamber of Commerce and Industry of Slovenia (CCIS, https://www.gzs.si/), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Inštitut za celulozo in papir (Pulp and Paper Institute), http://icp-lj.si/?lang=en

No biorefineries belonging to the categories in the study have been identified.

6.4.27 Spain

Spain has a dedicated bioeconomy strategy at the national level.[79]

In Spain, there are 10 pulp mills and 70 paper and board mills in operation.[80]

The national pulp and paper association, the Spanish Association of Pulp and Paper Manufacturers (ASPAPEL http://www.aspapel.es/en), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- Universitat Politècnica de València, https://www.upv.es/index-en.html?

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Ence Pontavedre, https://ence.es/en/biofactories/pontevedra-biofactory/
  - Ence Navia, https://ence.es/en/biofactories/navia-biofactory/
  - Zubialde, http://www.zubialde.com/index.html
  - IberPapel, http://www.iberpapel.es/en/
- Planned – not identified

6.4.28 Sweden

Sweden has a dedicated bioeconomy strategy at the national level.[81]

There are 36 pulp mills and 38 paper and board mills in operation.[82]

[78] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[79] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[80] CEPI Annual Statistics 2018
[81] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en
[82] CEPI Annual Statistics 2018

The national association, the Swedish Forest Industries Federation (https://www.forestindustries.se/), is a member of Cepi.

The major institutes related to wood-based bioproducts are as follows:

- RISE, https://www.ri.se/en
- KTH, https://www.kth.se/en
- Chalmers University of Technology, https://www.chalmers.se/en
- Karlstad University, www.kau.se
- Luleå University of technology, www.ltu.se
- Lund University, www.lth.se
- Mid Sweden University, www.miun.se

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
    - Aditya Birla Group, Örnsköldsvik, http://www.domsjo.adityabirla.com/Sidor/Startsida.aspx
    - Ahlstrom-Munksjö Paper AB Billingsfors Bruk, Billingfors, https://www.ahlstrom-munksjo.com/
    - Ahsltrom-Munksjö Aspa Bruk, Aspabruk
    - BillerudKorsnäs, Frövi, https://www.billerudkorsnas.com/
    - BillerudKorsnäs, Gruvö
    - BillerudKorsnäs, Gävle
    - BillerudKorsnäs, Karlsborg
    - BillerudKorsnäs, Skärblacka
    - Hollmens Iggesunds bruk, Iggesund, https://www.holmen.com/
    - Metsä Board, Husum, https://www.metsaboard.com/Pages/default.aspx
    - Mondi Dynäs, Kramfors, https://www.mondigroup.com/en/home/
    - Nordic Paper Bäckhammar, Kristinehamn, https://www.nordic-paper.se/
    - Nordic Paper Säffle, Säffle
    - Rottneros Vallviks Bruk, Vallviks, https://www.rottneros.com/
    - SCA Munksund AB, Piteå, http://www.sca.com/
    - SCA Obbola AB, Obbola
    - SCA Östrands Massafabrik, Timrå
    - Smurffit Kappa, Piteå, http://www.kappa-kraftliner.com/
    - Stora Enso Nymölla, Nymolla, https://www.storaenso.com/
    - Stora Enso Pulp AB Skutskär bruk, Skutskär
    - Stora Enso Skoghall, Skoghall
    - Södra Cell Mönsterås, Mönsteros, https://www.sodra.com/
    - Södra Cell Mörrum, Mörrum
    - Södra Cell Värö, Väröbacka
    - Kraton, Sandarne, https://www.kraton.com/
    - Preem Ltd, Gotenburg, https://www.preem.se/en/in-english/
    - Sunpine Ltd, Piteå, https://www.sunpine.se/
    - LTU Green Fuels, Piteå, https://www.ltu.se/org/tvm/Avdelningar/LTU-Green-Fuels?l=en
    - SCA, Obbola, https://www.sca.com/en/
    - Södra, Mönsteros, https://www.sodra.com/en/

  - RISE LignoDemo AB, Bäckhammar, https://www.ri.se/en/what-we-do/expertises/lignin-science
  - Waggeryd Cell, Waggerryd, http://www.waggerydcell.se/
  - Melodea, Sweden, https://melodea.eu/
- Planned
  - SunPine, Piteå, https://www.sunpine.se/
  - Preem, Gotenburg, https://www.preem.se/en/in-english/
  - Renfuel, Stockholm, https://renfuel.se/?lang=en
  - ST1 and SCA, Gotenburg, https://www.st1.eu/
  - Preem, Gotenburg, https://www.preem.se/en/in-english/
  - SunCarbon, Lund, https://suncarbon.se/en/home/
  - RenCom, Knivsta, https://www.lignin.se/
  - Stora Enso, Fors mill, https://www.storaenso.com/

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - Stora Enso Hylte Mill, Hylte, www.storaenso.com
  - Fiskeby Board Ltd, https://www.fiskeby.com/?lang=en
- Planned
  - Stora Enso Nymolla Paper mill, Nymolla, www.storaenso.com

CAT3. Other biorefineries using wood as raw material to produce various existing or evolving bio-based products

- Active – not identified
- Planned
  - Pyrocell, Gävle, https://www.setragroup.com/en/pyrocell/
  - SCA Biorefinery Östrand AB, Timrå, http://www.sca.com/
  - Ecohelix, Domsjö, https://www.ecohelix.se/

6.4.29 Switzerland

In Switzerland, a dedicated bioeconomy strategy at the national level is under development.[83]

There is no pulp production in the country. There are three paper mills in operation.

The national association, the Association of the Swiss Pulp, Paper and Board Industry (https://spkf.ch), is not a member of Cepi.

The major institutes related to wood-based bioproduct research:

- Bern University of Applied Sciences, https://www.bfh.ch/ahb/en/

No biorefineries belonging to the categories in the study have been identified.

[83] https://ec.europa.eu/knowledge4policy/visualisation/bioeconomy-different-countries_en

6.4.30 United Kingdom

The UK has a dedicated bioeconomy strategy at the national level.[84]

The UK has 46 paper and board mills, including two integrated thermo-mechanical mills.

The national association, the Confederation of Paper Industries (https://paper.org.uk/) is a member of Cepi.

The major institutes related to wood-based bioproduct research are integrated into the High Value Manufacturing Centre Strategy, https://hvm.catapult.org.uk/our-centres/.

Additionally, a number of universities have Material Science Centres, though none exclusively focused in wood-based processing. Three universities traditionally specialise in forest management issues – Edinburgh, Oxford and Bangor.

CAT1. Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products

- Active
  - Lenzing Fibers Grimsby Ltd, https://www.lenzing.com/lenzing-group/locations
  - FiberLean Technologies, https://www.fiberlean.com/
- Planned – not identified

CAT2. Biorefineries using virgin pulp or/and recycled fibres to produce various existing or evolving bio-based products

- Active
  - SAICA Containerboard, www.saica.com
  - Smurfit Kappa SSK, https://www.smurfitkappa.com/
  - Smurfit Kappa, https://www.smurfitkappa.com/
- Planned – not identified

7 R&D programs and consortiums of the evolving bio-based products

7.1 General

In order to carry out this task, it was decided to list the on-going biorefinery and bio-based product projects in Europe. R&D projects have been collected from the FTP-database[85], which "is a comprehensive piece of open source data infrastructure that compiles ongoing and concluded research and innovation activities carried out by the European forest-based sector, as well as details on relevant funding opportunities". Since the database was formed, there has been around 1000 projects listed, they were refined by selecting the time period 2017 – 2020, and from those the most relevant on-going and recently completed projects were found and listed. The typical project duration at EU level is four years. In addition, surveys for the main European institutes were conducted via the Webropol[86] system. The questionnaire includes questions relating to the most interesting R&D programs for biorefineries and bio-based products. At this level, the duration of the projects varies from one to four years.

To classify the projects in both cases, they were divided into the following categories based on the final products: materials, chemicals, fuels, food/feed and pharmaceuticals/cosmetics.

7.2 Findings

Table 10 shows EU funded R&D projects identified (fully or partly funded with public money) and table 11 shows the R&D projects identified via the Webropol system. Note! the listed ones are only R&D projects in tables which do not involve a direct link to the construction of a biorefinery.

Table 10. R&D projects via FTP database.

Category	Number	Share, %	Budget, M€	Share, %	Biorefinery category 1	Biorefinery category 2	Biorefinery category 3
Materials	24	48.0	130 327 399	55.5	8	7	9
Chemicals	13	26.0	36 165 655	15.4	5	2	6
Fuels	11	22.0	44 598 076	19.0	0	0	11
Food and Feed	1	2.0	14 976 590	6.4	0	0	1
Pharmaceuticals and cosmetics	1	2.0	8 775 679	3.7	0	1	0
In total	**50**	**100**	**234 843 399**	**100**	**13**	**10**	**27**
					26.0 %	**20.0 %**	**54.0 %**

Biorefinery category 1: Biorefineries based on chemical pulping operations to produce various existing or evolving bio-based products. Biorefinery category 2: Biorefineries using virgin pulp and/or recycled fibres to produce evolving bio-based products. Category 3: Other biorefineries using lignocellulose as raw material to produce various existing or evolving bio-based products

[85] http://db.forestplatform.org/#!/research-projects/index
[86] https://webropol.fi/

Table 11. R&D projects via the Webropol system.

Category	Number	Share, %	Biorefinery category 1	Biorefinery category 2	Biorefinery category 3
Materials	27	81.8	13	10	4
Chemicals	4	12.1	1	0	3
Fuels	1	3.0	1	0	0
Food and Feed	0	0.0	0	0	0
Pharmaceuticals and cosmetics	1	3.0	0	0	1
In total	**33**	**100**	**15**	**10**	**8**
			45.5 %	**30.3 %**	**24.2 %**

As seen in Table 10 most of the projects were focused on materials and biorefinery projects from category III as defined in this report, while Table 11 indicates that most of the projects were focused on materials and biorefinery projects from category I. It can be also concluded that the forest sector and the pulp and paper industries seem to be not so active in food/feed and pharmaceutical/cosmetics R&D projects today.

More detailed data of the EU level R&D projects are listed in Appendix 2. Detailed data via the Webropol system are not given in this report due to their confidentiality.

8 Discussion

The study is an ideal tool to gauge the development of bio-based products and biorefineries in Europe. In the study EU27 countries as well as Norway, UK and Switzerland were investigated.

During the survey it was recognised that there is a need to collect a database focusing on emerging bio-based products. There is frequent news relating to these products, but not really a holistic overview as to what the status is of the emerging bio-based products in terms of their prevalence – how much they are already in commercial production and those that are already in investment pipelines. Also, it was very interesting to analyse where the focus is when it comes to R&D programs related to emerging bio-based products. As there is not already a reference database of emerging bio-based products in the forest industry, the project put in efforts to define a framework for these types of studies and surveys.

As developments in biorefineries progress relatively quickly, it is recommended to periodically update the database to monitor future developments, e.g. every second year. As Cepi has already published the results of this survey, it is recommended that the first review should take place in mid-2021 as companies will be more aware of the content of the database.

The database of biorefineries and bio-based products was created and built during the exceptional time of the COVID-19 pandemic, when companies were in the middle of adapting and navigating the unprecedented turmoil the virus brought. We expect that this has had some impact on retrieving the companies' information about bio-based products. It is anticipated that the understanding of biorefineries will increase as the report will be published at the beginning of 2021, leading to more insights in actual existing biorefineries as well as a growing amount of biorefinery activities.

Based on the study, the largest share of bio-based products is related to materials applications. Out of materials, man-made fibres are among the largest in the sector. The global textile market is over 100 million tons with just 6% being based on cellulosic textile fibres. Europe is currently producing 10% of cellulosic textile fibres. It is expected that man-made cellulosic fibres' share will increase during the vision 2050 time period. To fill this gap, it is expected that more and more traditional kraft mills will be converted to produce dissolving pulp.

In the near future there will be several biofuel production investments. These biorefineries are based on using crude tall oil as a feedstock. The limiting factor is tall oil availability, which will soon be exploited for use in other biobased products. Another route to produce biofuels is the use of residuals and other side-streams as a feedstock. One potential route is utilisation of lignin from the black liquor from kraft mills to produce lignin oil. A further route to produce biofuels is based on fermentation, which normally leads to lower yields reducing profitability. In the case of using residuals there is also the question of what to do with all lignin extracted in the process, of which the quality differs to kraft based lignin. So, in most of the cases, these investments will survive as long as there is a regulatory frame to support these investments and operations.

Biochemicals is an interesting sector. At the moment only a few companies are advancing in this field by announcing substantial investments. Once these are established, it is expected we will see more and similar types of announcements.

According to the study results for time being there is less activities related to food and feed as well as pharmaceuticals and cosmetics. For now, there is only a small number of announcements noted.

Based on on-going R&D programs, it is expected that there will be again more investments in the material sector – which is currently dominating in terms of R&D programs in number but also in terms of R&D program value. This can be partially explained by the fact that yields for material solutions are often high in comparison to chemical and fuel applications.

Once the study was launched, there were special requests to see how recycled fibres fit to the biorefinery concepts. Quite some recycled paper mills are active in valorising their side steams (deinking sludge, waste water treatment sludges, rejects, etc.), though this is often performed as 'cost and/or raw material efficiency' measure, and it is not called 'biorefinery' in those industries. During this biorefinery survey, therefore there were unfortunately not too many cases showing that recycled fibre side streams are used for new emerging applications. We hope that this report will inspire those companies in the next update to have their activities and plans included as well.

9 Conclusions

The *Biorefineries in Europe* study is the first of its kind conducted on such a large scale and it provides a basic framework for updates in coming years. As the year 2020 was exceptional due to the pandemic it is recommended that the study is reviewed in the near future. The study has created a basic, but effective database, which is easy to update periodically as the industry evolves.

Biorefining in Europe is an evolving sector. The current value of evolving bio-based products is less than 3% of the total industry value as represented by Cepi. This is still relatively small, but it is a good starting point when bearing in mind that the target is to increase its value substantially as per the vision to 2050.

The total number of active biorefineries included in this study is 139. The most common biorefinery type in Europe is CAT 1 (chemical pulping based biorefineries) accounting for 84% of all active biorefineries. Also planned biorefineries were listed. The share of CAT 2 (paper mill based biorefineries) and CAT 3 (biorefineries based on new processes) types of biorefineries is larger in comparison to active biorefineries, being about 20% each. In total there are 28 announced plans of biorefineries in Europe (in 18 Cepi related countries). This does not mean necessarily totally new greenfield sites, but there are product expansions towards bio-based products listed in this study.

The majority of the existing biorefineries in Europe are based on chemical pulping processes. The second biggest group are biorefineries mainly using side-streams of existing paper, board and tissue mills. We expect this amount may be bigger than included in this report, as the valorisation of side streams from paper mills is generally not called a biorefinery and may thus not be identified in the survey. There are few totally new types of biorefineries, which are based on emerging separation methods of wood.

The current turnover of the European pulp and paper industry is close to €90 billion.

Following the study methodology, the value of emerging bio-based products which are already actively produced is €2.65 billion. This corresponds to close to 3% of the pulp and paper industry turnover. This number is relatively small today as expected. But we have to remember that in accordance with vision 2050, it is expected that emerging bio-based products will play a bigger role.

When we compare different categories, the largest value is related to CAT 1 type of biorefineries – almost 95% of the total. In the future, the value of CAT 3 types of biorefineries will increase – already based on today's investment plans it is accounting for almost a quarter of all planned biorefineries.

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Appendixes

Key definitions by Cepi STA/17/007b

Bioeconomy[1]: The bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy

Biomass[2]: 'biomass' means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste

Biorefinery[3]: The simultaneous production of bioenergy, biomaterials and biochemicals takes place in biorefineries. In a biorefinery, analogous to a petroleum refinery, biomass feedstocks are converted into energy, fuels or other products using a range of thermochemical and biochemical processes.

Woody biomass usages

Traditional products

Fibres		**Main sector of use**	**Main products**
Round wood	Saw log	Sawn wood	Wood Construction, Furniture & Packaging, etc.
		Plywood	Plywood, particle board, Fibreboard, Veneer Sheets
	Pulpwood, Paper for Recycling	Pulp	Paper pulp, Dissolving pulp, Fluff pulp
		Paper and Board	Graphic paper, Packaging paper & board, Sanitary & household paper, Speciality paper, other paper and board

Energy

	Main sectors of use	**Main products**
Residues from forestry, pulp & paper mills, sawmills	Heat	Heat
	Power	Power
	Wood pellet	Wood pellet

New bio-based products

	Main sectors of use	**Main products**
Biomass	Fuel	Bio-cellulosic ethanol, bio oils, bio-gas, biodiesel, heating oil, etc.
	Chemicals	Adhesives, disinfectants and detergents, drilling fluids, paint and dyes, etc.
	Food and feed	Flavourings, preservatives, texturizers and emulsifiers, anti-caking agents and stabilizers, etc.
	Materials	Natural fabric dyes, pig iron, asphalt roofing sheets, carbon fibre, thermoplastics, synthetic viscose fibre, alternative to metallic materials, bio-plastics, cellulose foams, flexible and LCD screens, etc.
	Cosmetics, personal hygiene, medical and pharmaceutical	Essential oils, medication, cosmetics, personal hygiene products, etc.

[1] (COM(2012) 60 final) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - Innovating for Sustainable Growth: A Bioeconomy for Europe.

[2] (DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC)

[3] EU Commission DG Research & Innovation

Appendix 2

What a tree can do?

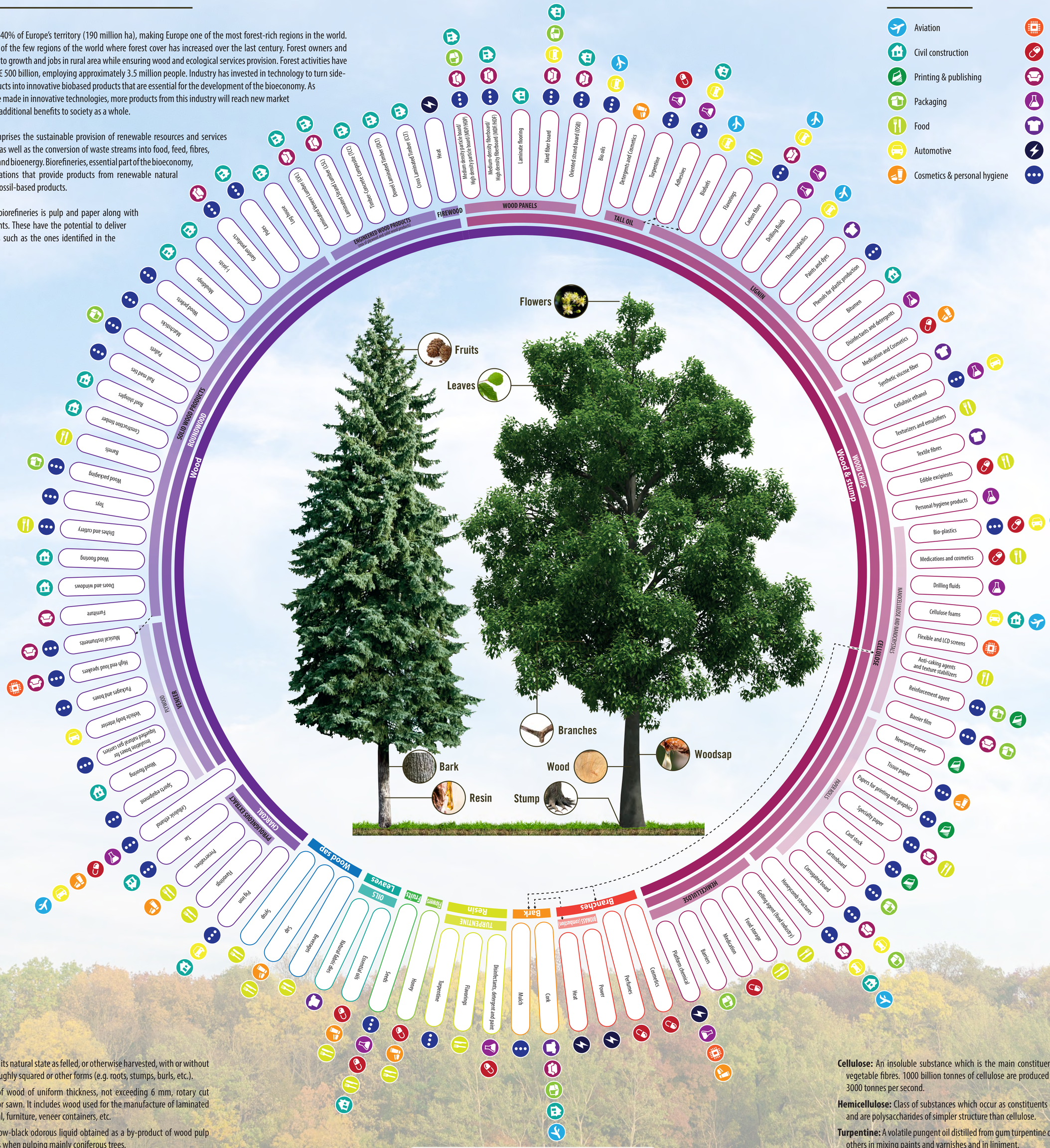
Forests cover around 40% of Europe's territory (190 million ha), making Europe one of the most forest-rich regions in the world. Europe is in fact one of the few regions of the world where forest cover has increased over the last century. Forest owners and managers contribute to growth and jobs in rural area while ensuring wood and ecological services provision. Forest activities have a turnover of almost € 500 billion, employing approximately 3.5 million people. Industry has invested in technology to turn side-streams and by-products into innovative biobased products that are essential for the development of the bioeconomy. As more investments are made in innovative technologies, more products from this industry will reach new market segments, providing additional benefits to society as a whole.

The bioeconomy comprises the sustainable provision of renewable resources and services and their conversion as well as the conversion of waste streams into food, feed, fibres, materials, chemicals and bioenergy. Biorefineries, essential part of the bioeconomy, are industrial installations that provide products from renewable natural resources, replacing fossil-based products.

A great example of biorefineries is pulp and paper along with wood processing plants. These have the potential to deliver a wealth of products such as the ones identified in the poster.

Industries

- Aviation
- Civil construction
- Printing & publishing
- Packaging
- Food
- Automotive
- Cosmetics & personal hygiene
- Electronics
- Pharmaceutical & medical
- Furniture
- Chemicals
- Textile
- Energy
- Various industries



Roundwood: Wood in its natural state as felled, or otherwise harvested, with or without bark, round, split, roughly squared or other forms (e.g. roots, stumps, burls, etc.).

Veneer: Thin sheets of wood of uniform thickness, not exceeding 6 mm, rotary cut (i.e. peeled), sliced or sawn. It includes wood used for the manufacture of laminated construction material, furniture, veneer containers, etc.

Tall oil: A viscous yellow-black odorous liquid obtained as a by-product of wood pulp manufacture process when pulping mainly coniferous trees.

Plywood: A panel consisting of an assembly of veneer sheets bonded together with the direction of the grain in alternate plies generally at right angles.

Cellulose: An insoluble substance which is the main constituent of plant cell walls and vegetable fibres. 1000 billion tonnes of cellulose are produced every year, equivalent to 3000 tonnes per second.

Hemicellulose: Class of substances which occur as constituents of the cell walls of plants and are polysaccharides of simpler structure than cellulose.

Turpentine: A volatile pungent oil distilled from gum turpentine or pine wood, used among others in mixing paints and varnishes and in liniment.

Lignin: A class of complex organic polymers that form important structural materials in the support tissues of plants and algae.

CEI-Bois cepi CEPF eustafor

Appendix 3. Selected biorefinery and bio-based product R&D programmes 2017 – 2027

Materials

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
1	FRESH / Fully bio based and bio degradable ready meal packaging	barrier for meal trays	completed, 07/2020	10 641 000	1
2	Production and deploying of high purity lignin and affordable platform chemicals through wood-based sugars	high purity lignin as well as C5 and C6 carbohydrates	ongoing	43 233 731	3
3	Green chemicals and technologies for the wood-to-textile value chain	man-made fibers	ongoing	2 788 444	1
4	NOVUM - Pilot line based on novel manufacturing technologies for cellulose-based electrical insulation components	cellulose-based electrical insulation components and 3D printing of cellulose-based materials	ongoing	8 491 019	1
5	Torero - TORrefying wood with Ethanol as a Renewable Output: large-scale demonstration	biocoal and bioethanol	completed, 04/2020	15 849 490	3
6	Process developments for a recyclable and compostable all-cellulose multilayer material for packaging, CelluWiz	all-cellulose packaging materials	ongoing	2 841 875	2
7	SHERPACK - Innovative structured polysaccharides-based materials for recyclable and biodegradable flexible packaging	biobased barrier for flexible paper-based packaging material	on-going	2 589 095	2
8	PAPERCHAIN - New market niches for the Pulp and Paper Industry waste based on circular economy approaches	secondary raw materials for construction sector, mining sector and chemical industry.	ongoing	9 217 196	2

Materials continues…

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
9	Innovative and Smart Printed Electronics based on Multifunctionalized Paper: from Smart Labelling to Point of Care Bioplatforms (INNPAPER)	multifunctional paper	ongoing	7 416 491	2
10	ECOFIPS - Ecological Fibres for Insulation, Pulp and Substrate	ligno-cellulose fibre	completed	71 429	3
11	NewSiest - Enhancement of UV stability of thermally modified wood through envelope impregnation with nano-based stabilisers	nano-stabilizer coatings	on-going	162 040	3
12	EUCALIVA - EUCAlyptus LIgnin VAlorisation for Advanced Materials and Carbon Fibres	lignin	on-going	2 419 871	1
13	FRESHTRAY - New corrugated cardboard for active packaging to extend shelf-life of fresh fruits and vegetables	cardboard with anti-microbial coating	completed	71 429	2
14	TOPIS-BioCirc - Integrating torrefaction of pulp and paper industry sludge with microbial conversion: A new approach to produce bioenergy carriers and biochemicals in a view of bio and circular economy	bio-coal, bio-methane, volatile fatty acids	on-going	154 193	2
15	SULACHANGE - Microplastic-free Sulapac-material challenges plastic	Sulapac® (bioplastics)	on-going	2 763 125	1
16	NanoTextSurf - Nanotextured surfaces for membranes, protective textiles, friction pads and abrasive materials	nanostructured surfaces	on-going	6 599 711	1
17	BIOMOTIVE - Advanced BIObased polyurethanes and fibres for the autoMOTIVE industry with increased environmental sustainability	Advanced bio-based materials (i.e. thermoplastic Polyurathanes, 2-k thermoset polyurethane foams and regenerated natural fibres) specifically for the automotive industry	On-going 06 2017 – 05 2021	15 186 325	3
18	CLEANFUL - Clean and low costs paper-based batteries for powering single use disposable diagnostic devices	Paper-based batteries	Completed, 12 2017 – 04 2018	71 429	2

Materials continues…

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
19	COMSYN - Compact Gasification and Synthesis process for Transport Fuels	FT products to biofuels	On-going, 05 2017 – 04 2021	5 096 660	3
20	Cellsorb - Cost-efficient and safe cellulosic food pad	Food pad absorbers	Completed, 04 2020 – 03 2022	3 290 163	1
21	POLYWOOD - Combining wood and polymers to produce a translucent, reinforced and ecological material	translucent wood, three times stiffer than natural wood, much more durable, water and fire	Completed 08.2018	79 375	3
22	WoCaFi - Unlocking the Entire Wood Matrix for the Next Generation of Carbon Fibers	These bio-based, low cost carbon fibers will reduce the dependency on non-renewable petroleum-based feedstocks and are highly suitable for lightweight applications in the automotive, sports and leisure sectors.	NA	1 481 008	3
23	WoodNanoTech - Wood Nanotechnology for Multifunctional Structures	lighting systems, LED panels, wood lasers, electrochromic windows or load-bearing and transparent panels	On-going 09.2017 - 08.2022	2 461 947	1
24	Woodoo Augmented Wood - transforming wood into construction material strong as concrete and translucent as amber	auto interiors, lightweight car chassis and sustainable wooden buildings	On-going 09.2019 - 08.2020	3 245 778	3

Chemicals

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
1	Valorise Extensive quantities of HemIcellulosic and Cellulosic sugars from Lignocellulosic biomass into high-value End products, VEHICLE	glycols (MEG and MPG), butanediol and long chain diacids and specialty sugars (glucosone, fructose)	ongoing	9 641 857	1
2	UNique Refinery Approach to Valorise European Lignocellulosics, UNRAVEL	lignin fragments and monomeric sugars from the cellulose and hemicellulose fraction suitable for biochemical conversions.	ongoing	3 717 296	3
3	Extremozymes for wood based building blocks: From pulp mill to board and insulation products	bio-based precursors for adhesives in the manufacture of medium-density fiberboards, and as components of insulation polyurethane foams (substituting fossil building blocks), as well as for obtaining renewable sugar-based papermaking additives.	ongoing	5 207 319	1
4	LIGNIOX - Lignin oxidation technology for versatile lignin dispersants	various dispersants, specially high-performance concrete and mortar plasticizers	on-going	5 588 988	1
5	NewSiest - Enhancement of UV stability of thermally modified wood through envelope impregnation with nano-based stabilisers	nano-stabilizer coatings	on-going	162 040	3
6	FRESHTRAY - New corrugated cardboard for active packaging to extend shelf-life of fresh fruits and vegetables	cardboard with anti-microbial coating	completed	71 429	2
7	ECOHELIX has developed a technology which transforms widely available, sustainable, pulp industry waste into high-performance polymers	The end product can replace petroleum-based products such as PVOH, PVAc and SDS	Completed 02 2019 – 07 2019	71 429	1
8	BiMetaCat - Two Are Better Than One: Bimetallic Catalysts for the Conversion of Lignin-Derived Aryl-Ethers	Aromatic building blocks	On-going, 04 2019 – 03 2021	187 572	3

Chemicals continues…

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
9	CATLIGCAR - Designing Novel Efficient Catalytic Strategies for the Transformation of Lignocellulose into Lignin-derived Chemicals and Valorisable Carbohydrates	Lignin-derived chemicals	Completed 10 2017 – 09 2019	172 800	3
10	CHBTECH Sulphur-free production method for non-food biopolymers (dissolving pulp, hemicellulose and lignin)	Wide variety of applications, e.g in textiles, chemicals, and plastics	On-going, 03 2019 – 02 2021	3 061 250	3
11	SELectiveLi - Conceptual Study of Electrochemical based novel process using Lignosulfonates to produce bio-based monomers & polymers	Targeted for CO2-neutral plastics, green building blocks, flavourings and fragrances	Completed 05 2019 – 04 2023, TRL3	2 853 119	1
12	Photoelectrochemical Hydrogen Production from H2S in a Regenerative Scrubber	saleable high-value commodity sulfur and renewably-derived hydrogen gas	Completed 06.2020	150 000	1
13	Sustainable and efficient bio-chemical catalytic cascade conversion of residual biomass to high quality biopolymers	bio-isoprene at 50% cost reduction and 3MPD at 70% cost reduction compared to average market prices,	On-going 01.2018 - 12.2020	5 351 985	3

Fuels

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
1	Sustainable Drop-In Transport fuels from Hydrothermal Liquefaction of Low Value Urban Feedstocks	drop-in quality synthetic gasoline and diesel fuels	On-going	5 074 876	3
2	REsidual soft WOod conversion to high characteristics drop-in bioFUELs, REWOFUEL	hydrolysate (RWH) and conversion of RWH into bio-Isobutene (bio-IBN) and biofuels	On-going	19 791 557	3
3	Chemical Looping gAsification foR sustainAble production of biofuels (CLARA)	liquid biofuels	On-going	4 993 805	3
4	FALCON - Fuel and chemicals from lignin through enzymatic and chemical conversion	lignin oil	ongoing	6 555 884	3
5	EFFIGAS - Innovative self-controlling biomass gasification technology to improve the biogas efficiency achieving a top quality syngas	syngas	completed	71 429	3
6	ProEMiBiL - Ethanol production from microalgae and lignocellulosic biomass	bioethanol	on-going	98 508	3
7	FLEXCHX - FLEXIBLE COMBINED PRODUCTION OF POWER, HEAT AND TRANSPORT FUELS FROM RENEWABLE ENERGY SOURCES	transportation fuels	on-going	4 489 545	3
8	NewLiEP - Injecting New Life into Cellulosic Ethanol Production	ethanol	on-going	4 112 500	3

Fuels continues…

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
9	ABC-SALT - Advanced Biomass Catalytic Conversion to Middle Distillates in Molten Salts	Biofuel	Ongoing 04 2018 – 03 2022	3 998 025	3
10	BioFuel Fab - Biogas production from non-food lignocellulosic biomass waste	Biogas	Completed 12 2019 – 05 2020	71 429	3
11	Technology for 2G biofuel and biosolvents production verified in a pilot plant	2nd generation environmental-friendly biofuel (biobutanol) and biosolvents (bioacetone, bioethanol)Process he technology is nnovative combination of two existing technologies, where the first is pre-treatment of biomass with follow-up production of sugars and second one is ABE technology, for production of biobutanol, bioacetone and bioethanol, where raw material are C5 and C6 sugars.	Completed 07.2019	71 429	3

Food and Feed

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
1	SYLFEED - From forest to feed: enable the wood industry to bridge the protein gap	Single Cell Protein (SCP) to be used as animal feed (mainly for fishes).	completed 08/2020	14 976 590	3

Pharmaceuticals and cosmetics

#	Name of the project Abbreviation + long name	Products	Status	Budget, €	Biorefinery category
1	Production of functional innovative ingredients from paper and agro-food side-streams through sustainable and efficient tailor-made biotechnological processes for food, feed, pharma and cosmetics	i) lactobionic acid (LBA), galactooligosaccharides (GOS), microbial safe biomasses from whey; ii) polyhydrohyalkanoates (PHA) enriched biomasses and purified PHA, as prebiotics and bioplastics respectively, from paper mill wastewater; iii) functional pre-fermented ingredients from rye/wheat milling fractions. Safe and characterized INGREEN ingredients will be used for innovative functional cheeses, bakery products and nutritious feeds. Functional GOS, LBA and pre-fermented bran will be used to produce prebiotic immune-stimulating gel, nutraceutical supplement and cleanser for human health. INGREEN biodegradable material will be valorised into bag in box to boost INGREEN fluid prototype sustainability.	On-going 06.2019 - 11.2022	8 775 679	2