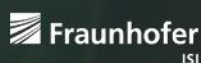


## D1.2

### Overall mapping of global and EUs policies on bio-based sectors & food-systems

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## List of Abbreviations

Abbreviation	Full name
ART	Agriculture Research Troubsko, Ltd
APRE	Agency for the Promotion of the European Research
BBEPP	Bio Base Europe Pilot Plant
BBI JU	Circular Bio-based Europe Joint Undertaking
BNCT	Biotechnology, Nanotechnology and Converging Technologies
BIC	Bio-based Industries Consortium
BIG-Cluster	BioInnovation Growth Mega-Cluster
BIOEAST	Central Eastern European Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bioeconomy
CAP	Common Agricultural Policy
CBE JU	Circular Bio-based Europe Joint Undertaking
CCU	Carbon Capture and Utilization
CEAP	Circular Economy Action Plan
DG	Directorate General
DOC	US Department of Commerce
DOE	US Department of Energy
EAFRD	European Agricultural Fund for Rural Development
EAGF	European Agricultural Guarantee Fund
EBPF	European Bioeconomy Policy Forum
ECBF	European Circular Bioeconomy Fund
ECCP	European Cluster Collaboration Platform
EFSI	European Fund for Strategic Investments
EIB	European Investment Bank
EIC	European Innovation Council
EMFAF	European Maritime, Fisheries and Aquaculture Fund

EO	Executive Order
ERA	European Research Area
ERDF	European Regional Development Fund
ESG	Environmental, Social and Governance
EU	European Union
EuBioNet	European Bioeconomy Network
FAO	Food and Agriculture Organisation of the United Nations
FBCD	Food & Bio Cluster Denmark
Fraunhofer ISI	Fraunhofer Institute for Systems and Innovation Research
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
HHS	US Department of Health and Human Services
IPR	Intellectual Property Rights
ISBWG	International Sustainable Bioeconomy Working Group
JRC	Joint Research Center
K4P	Knowledge for Policy
MR	Macro-Region
MS	Member State
NACE	Nomenclature of Economic Activities
NASEM	National Academies of Sciences, Engineering, and Medicine
NBP	National Biotechnology Policy
NDC	Nationally Determined Contribution
NDRC	China's National Development and Reform Commission
NSF	US National Science Foundation
OECD	Organisation for Economic Co-operation and Development
OSTP	The Office of Science and Technology and Policy
R&D	Research and Development



RDP	Rural Development Programme
RED	Renewable Energy Directive
RTA	Revealed technological advantage
SCAR	Standing Committee of Agricultural Research
SDG	Sustainable Development Goal
SME	Small and Medium Size Enterprise
SRIA	Strategic Research and Innovation Agenda
SUBNET	SUBMARINER Network for Blue Growth
TRL	Technology Readiness Level
TTG	Tech Tour Global
TTE	Tech Tour Europe
UK	United Kingdom
UN	United Nation
US	United States
USDA	US Department of Agriculture
VCM	Voluntary Carbon Market

## Executive Summary

This report provides an inventory of the bioeconomy initiatives, instruments and key innovation indicators for the European Union (EU), based on the identified information needs in the ShapingBio project. Furthermore, key insights from the international level are also provided.

Chapter 2 of the report presents an overview of the key global-level organizations and initiatives (e.g., Organization for Economic Cooperation and Development (OECD), Food and Agriculture Organization of the United Nations (FAO), World Bioeconomy Forum) comprising their role and purpose in bioeconomy development. Furthermore, information on key global players (i.e. the United States (US), China, Japan,) in bioeconomy will be also provided. In 2012, the EU was considered a global frontrunner in bioeconomy, for launching the EU Bioeconomy strategy, which was revised and re-adopted in 2018 to establish an EU-wide approach to overcome the innovation valley of death in bioeconomy. The strategy has a very wide approach and it focusses on all sectors of the bioeconomy: agriculture, bio-based chemicals and materials, bio-based textiles, bioenergy, biotechnology, fisheries and aquaculture, food, forestry, waste, pulp paper wood products and more (European Commission, 2012). When comparing the EU Bioeconomy Strategy to other strategies of global players, we see substantial differences not only in the prioritization of topics but also in the operational mode. Furthermore, other regions have emerged to be more forward-leaning in recognizing the importance of bioeconomy, especially the US and China. If Europe wants to realize its full potential in the bioeconomy, the EU policy makers need to act more strategically to catch up with competitors and build on the technological progress made so far.

Chapter 3 focuses on EU state of play in bioeconomy and gives an overview of the current status quo of the sector. This includes the latest trends of key indicators, such use of biomass, primary production of the core sectors (i.e. agriculture, forestry, fisheries and aquaculture), which has increased constantly within the time duration. The agricultural sector is by far the largest biomass provider in Europe with more than 70%. However, the relative importance of the marine-based sectors in the bioeconomy is very high compared to their extremely low share of total biomass, because of algae production, which is a valuable resource for the EU's food and chemical industry. Chapter 4 provides some insights into EU bioeconomy policy landscape, by describing key European bioeconomy strategies, which play a paramount role in the European Bioeconomy. Furthermore, selected key policy instruments are also described. The description of the policy instruments in this report does not claim to provide a list of all instruments in the bioeconomy, but an overview of how these instruments affect the achievement of policy goals in the bioeconomy. Finally, a mapping of transnational collaborative structures in the EU is provided, which focuses on knowledge and information exchange, research and innovation facilitation, business development and collaboration, and policy advocacy and governance. The mapping provides an initial overview, from which a further selection will be made later on in the project to analyse how they address different challenges related to collaboration and which good practice can be derived from these examples.

The transition to the bioeconomy is still considered in an early-stage development phase that needs investments in innovation to strengthen itself and increase its value. Innovations in bioeconomy are interdisciplinary by nature. Many of them are at a low level of technological readiness for their implementation, which implies requirements for research organizations and the production of new applicable research and development (R&D) results. On the EU level, Horizon 2020 and Horizon Europe are the key funding mechanisms to support R&D activities of bioeconomy in Europe. However, it is important to note that the majority of it has been granted to

Western European countries<sup>1</sup> and e.g. less than 10% has been allocated to Central and Eastern European countries. Similar results are obtained for other innovation indicators. In terms of patenting in the EU bioeconomy sector, we see that the European bioeconomy sector's patenting levels remain second after the US across all different technologies in the bioeconomy sector. Even though China is investing heavily in innovation and the total rate of patent applications has been steadily increasing since 2010, the patenting activities are still lower than in the EU27 and the US across all the technology fields, related to bioeconomy.

Chapter 4 provides some insights into EU bioeconomy policy landscape, by describing key European bioeconomy strategies, which play a paramount role in the European Bioeconomy. Furthermore, selected key policy instruments are also described. The description of the policy instruments in this report does not claim to provide a list of all instruments in the bioeconomy, but an overview of how these instruments affect the achievement of policy goals in the bioeconomy. Finally, a mapping of transnational collaborative structures in the EU is provided, which focuses on knowledge and information exchange, research and innovation facilitation, business development and collaboration, and policy advocacy and governance. The mapping provides an initial overview, from which a further selection will be made later on in the project to analyse how they address different challenges related to collaboration and which good practice can be derived from these examples.

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<sup>1</sup> In ShapingBio we differentiate between four Macro-Regions (MR) in the EU. The MRs are the Baltic-Sea region (EE, LV, LT, FI, SE), Central & Eastern Europe (BG, CZ, HR, HU, PL, RO, SI, SK), Western Europe (BE, FR, DE, LUX, NL, IE, AT), and Southern Europe (ES, PT, MLT, IT, CYP, GR).

## 1 Introduction

The current fossil-based economy has reached its limits and needs radical transformation towards a new bioeconomy-based socio-economic model with more sustainable and circular use of resources. Over the last decade, this transition process has become one of the EU's core tasks and challenges.

The term 'bioeconomy' was first used decades ago to justify the biological roots of all economic processes and define economic entropy as a complex process of continuous and irremediable degradation of the potential of existing resources (Georgescu-Roegen, 1977). It took 35 years till the concept became popular when the EU launched the Bioeconomy Strategy (European Commission, 2012) defining Bioeconomy as "renewable production of biological resources and the transformation of these resources and waste streams into value-added products, such as food, feed [and] bio-based products, as well as bioenergy" (European Commission, 2012).

In the same year the European Commission, based on the conclusions of the reports and consultations of the interested parties, disseminated a document that combines strategies and action plans called "Innovating for sustainable growth: a bioeconomy for Europe" with key goals to provide the vital guidelines for innovation and research agendas in the areas of bioeconomy, support for a more prosperous political environment and seek ways for a more innovative, competitive and effective European community in the use of resources (De Besi et al., 2015). The updated Strategy in 2018 reaffirmed the five original objectives: (i) ensure food and nutrition security; (ii) manage natural resources sustainably; (iii) reduce dependence on non-renewable, unsustainable resources; (iv) mitigate and adapt to climate change; (v) strengthen European competitiveness and create jobs (European Commission, 2022a). These objectives are in line with the targets of the EU Green Deal and become more relevant than ever before, following the Russian invasion of Ukraine and the need to speed up EU's independence on energy and strengthening food security (European Commission, 2022a).

United Nations (UN) advocated for bioeconomy somewhat later in 2015 when developing 17 Sustainable Development Goals to be achieved by 2030 ('The 17 Goals', 2015). The report of FAO "The future of food and agriculture – Alternative pathways to 2050" states that global environmental risks are increasing and, therefore, all countries without exception in the next 30 years have to transform their food and agricultural systems and make them sustainable in the long run; FAO specialists emphasise the importance of bridging the knowledge gap over sustainable, development of food and agricultural systems and combining efforts of different countries, international organisations, civil society and academia (FAO, 2018a).

Even though the urgency of further development of bioeconomy and its importance to the economy has been recognized both on the EU and international level, different gaps and barriers remain, ranging for example from further optimization of biomass production and use to coherent policy support and financing opportunities. Insights on these aspects in the EU and its comparison with other global competitors are further elaborated in the following chapters of the current report. It provides an inventory of the bioeconomy initiatives, instruments and key innovation indicators for the EU, based on the prior identified information needs in the project. This report (Deliverable 1.3) will be accompanied by a more detailed EU member states analysis as part of the macro-regional mapping (Deliverable 1.4). Hence, the distribution of bioeconomy activities in the EU is not the core focus and therefore not analysed in detail in this report.

The report is structured in three pillars. First, a global perspective is taken, which enables us to set the European action into context and comparison. Moreover, there is a global dimension, in which the European bioeconomy actors can exchange knowledge and foster cooperation with partners internationally. Second, a state-of-play of the bioeconomy in the EU is provided, by

focussing mainly on innovation indicators, which shape the future of the bioeconomy. In addition, we focus on cross-national collaborative structures in the EU, which may have a particular function to foster joint activities and exchange for bioeconomy activities. Lastly, we map the current EU strategies and policies with high relevance for the bioeconomy.

## 2 International Overview

Over the last decade, the interest in bioeconomy has increased and a lot of countries have increasingly started focusing their attention on bioeconomy-based economic development. The number of dedicated bioeconomy strategies is increasing worldwide, as are regional and international strategies at different levels (e.g. the EU, Nordic countries and East Africa), which in turn also help to coordinate and streamline national-level efforts. Almost 60 countries were identified by the fourth Global Bioeconomy Policy Report (International Advisory Council on Global Bioeconomy, 2020) to be pursuing bioeconomy-related policies. In the following section strategic policy setting in the bioeconomy of key global countries is presented, namely from the US, China and Japan. Specific focus is the definition and coverage of the bioeconomy, policy coordination as well as goals and broad envisaged action lines. Afterwards, key global organizations (i.e., OECD and FAO) for policy making in the bioeconomy are described. This small selection complements later sections of the report, i.e. European situation as well as the Collaborative structures (Chapter 4.4).

### 2.1 Bioeconomy policies in selected non-EU countries

#### 2.1.1 United States

The US does not have a dedicated bioeconomy strategy, but the topic has been addressed by different policy actions and related documents. In 2012, the Office of Science and Technology Policy (OSTP) released a comprehensive vision for the US Bioeconomy (Office of Science and Technology Policy, 2012). However, the goals and objectives of the document are not well defined and remain unclear. Since 2016, the US Department of Agriculture and the Department of Energy has led federal efforts on the development of the US bioeconomy. Organizations, including the National Academies of Sciences, Engineering, and Medicine (NASEM), have urged the federal government to develop and regularly update of a comprehensive bioeconomy strategy to sustain and grow the US bioeconomy. On September 12, 2022, the Biden Administration issued an executive order creating the National Biotechnology and Biomanufacturing Initiative to accelerate bioeconomy innovation and growth in the US across multiple sectors (Executive Office of the President, 2023).

In 2020, the NASEM proposed the following definition of bioeconomy to be applied in the US context: “The US Bioeconomy is economic activity that is driven by research and innovation in the life sciences and biotechnology, and that is enabled by technological advances in engineering and in computing and information sciences” (NASEM, 2020). The NASEM groups US bioeconomy activities into three primary domains - agricultural, biomedical, and bio-industrial - in addition to “a cross-cutting category of tools, kits, and services” that advance biotechnology R&D. As estimated by the NASEM, the US bioeconomy sector accounted for more than 5% of US gross domestic product (GDP) or USD 959.2 billion in 2016. It is important to note that forestry is excluded in the bioeconomy scope in the US as it is hardly driven by biotechnology, which in parallel is included e.g., in the EU definition. As the proposed definition of bioeconomy by the NASEM indicates, one of the principal differences between the scope of the US bioeconomy and the bioeconomy of countries within the EU and Japan is the inclusion criteria of primary production sectors such as agriculture, fisheries, and forestry. In general, EU countries and Japan include these sectors wholly within their definition of the bioeconomy, while the US only selected parts are included (e.g., genetically modified crops and crops produced for energy). This difference also reflects the US view that biotechnology is considered as a key driver of the bioeconomy. Concerning the goals

and important steps for the bioeconomy in the US, there are several key documents from public authorities:

The Congressional Research Service (Congressional Research Service, 2022) raises several issues regarding the advancement of the US bioeconomy, including the development and implementation of a national bioeconomy strategy, federal investments in bioeconomy-related R&D, expanding the bioeconomy workforce, promoting and furthering the development of regional bioeconomies, increasing both the market for bio-based products and services, as well as public awareness and acceptance of bio-based products and services.

Potential benefits of a transition to a bioeconomy include the following aspects (Congressional Research Service, 2022, p.1):

- “The substitution of renewable biomass or bio-based raw materials for fossil fuels in the production of energy, chemicals, and materials;
- an increase in crop and livestock production;
- increased efficiency in the use of biomass and a reduction in waste;
- new drugs and diagnostics to improve human health;
- the creation of new jobs and industries;
- boosting rural development”.

Potential challenges associated with a transition to a bioeconomy and the successful development and commercialization of Bioeconomy-related products and services include (Congressional Research Service, 2022, p.1):

- “Ensuring policy coherence and alignment amongst the array of sectors involved;
- overcoming the “lock-in” or rigidity of existing production systems;
- ensuring equal access to Bioeconomy-related products and services; and
- prompting consumer acceptance and demand”.

According to the Executive Office of the President (2022), biomanufacturing is one of the key necessities in bringing innovative products of the Bioeconomy to a commercial scale. Furthermore, it is a common nominator for several global challenges such as resource utilisation, climate change, economic stability, and environmental justice. The Executive Order 14081, Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy, and the CHIPS and Science Act<sup>4</sup> are expected to further support the bioeconomy sector together with US scientific and technological pursuits in general.

One of the key priorities of the US Government is to ensure that the R&D performed in the US is primarily used for different domestic products and production processes in the US. This is already taking place successfully and the common efforts of the public and private sector have resulted in numerous new businesses and product innovations. Without these strategic decisions, prioritizations and support mechanisms it would be challenging for the US to maintain current global leadership in the biological sciences and bioengineering (Executive Office of the President, 2022).

In the same document, three key challenges were listed, which are critical in maintaining its leading role in the global bioeconomy scene.

- “US biomanufacturing capacity and workforce are not keeping pace with the bioproducts in development nor with the emerging biomanufacturing approaches that can expeditiously move new ideas and discoveries to commercial scale products. For an effective implementation, it is composed recommendations for Biomanufacturing Infrastructure Hubs.”



- “The regulatory review and approval process for many new cross-cutting bioproducts, particularly those emerging from new companies with innovative technologies, is complex and uncertain, which can delay or even stop the commercialization process.”
- “An integrated and overarching Bioeconomy strategy is needed to help guide Federal agencies in managing the development and transfer of these powerful biotechnologies toward social and economic advancements. This strategy should establish achievable objectives, provide options for adapting the strategy to a continually evolving Bioeconomy landscape, and identify data and metrics that will be used to monitor progress and reorient programs and funding.” (, p.8)

In 2022 The American President Executive Order was issued on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy (Executive Office of the President, 2022). It is oriented very closely to the definition by NASEM and defines some general actions like the expansion of market opportunities for bioenergy and bio-based products and services, etc. It names a set of agencies (see below) that have to implement these actions and coordinate with each other and were asked to submit reports within 180 days to further clarify how to use biotechnology and biomanufacturing in various to achieve the set goals.

On this basis, the White House Office of Science and Technology Policy published goals for the US Biotechnology and Biomanufacturing based on input from several Federal departments and agencies focussed on harnessing biotechnology and biomanufacturing innovation to further societal goals and transforming industries related to (Executive Office of the President, 2023,p.2).

- “Climate change solutions: In 20 years, demonstrate and deploy cost-effective and sustainable routes to convert bio-based feedstocks into recyclable-by-design polymers that can displace more than 90% of today’s plastics and other commercial polymers at scale.”
- “Food and agriculture innovation: By 2030, reduce methane emissions from agriculture, including by increasing biogas capture and utilization from manure management systems, reducing methane from ruminant livestock, and reducing methane emissions from food waste in landfills, to support the US goal of reducing greenhouse gas emissions by 50% and the global goal of reducing methane emissions by 30%.”
- “Supply chain resilience: In 20 years, produce at least 30% of the US chemical demand via sustainable and cost-effective biomanufacturing pathways.”
- “Human health: In 20 years, increase the manufacturing scale of cell-based therapies to expand access, decrease health inequities, and decrease the manufacturing cost of cell-based therapies 10-fold.”
- “Cross-cutting advances: In 5 years, sequence the genomes of one million microbial species and understand the function of at least 80% of the newly discovered genes. Reaching these bold goals will require progress in other areas beyond R&D to ensure that innovation can lead to safe, effective, and equitable products in our daily lives which grow the Bioeconomy across all of America and with our partners globally.”

These quantified goals for the upcoming 20 years are intended to provide a broad vision for the US Bioeconomy and what can be achieved with concerted action from industry, academia, non-profits, the federal government, and other organizations.

Regarding these goals, the Department of Energy (DOE), Department of Agriculture (USDA), Department of Commerce (DOC), Department of Health and Human Services (HHS), and National Science Foundation (NSF), respectively authored in-depth sections, with input from other federal departments and agencies.



All the topic areas and their respective goals require continued support for R&D and the establishment of public-private partnerships as well as consideration of biosafety and biosecurity. The goals require innovation across the biotechnology development spectrum, from basic science and prototyping to validation, clinical studies, manufacturing, and commercialization, culminating in regulatory approval. Therefore, building in sound biosafety and biosecurity practices that preserve critical discovery and innovation is a key component of the development of all referenced technologies.

According to the Executive Order ('Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy', 2022), an implementation plan will be elaborated based on those reports.

Taken together, the policy documents show a complex picture in terms how bioeconomy is addressed in different policy strategy documents in the US. Interestingly the recent publication from the Executive Office of the President (2023) includes concrete measurable goals and the participation of several key federal ministries. However, the concrete action plan still has to be defined and implemented.

### 2.1.2 China

In China, the term 'bioeconomy' is not commonly used in policy documents and strategies. Instead, a number of alternatives are used by policy makers across various documents, including Made in China 2025 and the Five-Year Plans, which refer either to biotechnology, the biotech industry, or the bioindustry as priority areas for development and growth (Congressional Research Service, 2022).

These terms all describe activities within the areas of biomedicine, biomedical engineering, agriculture biotechnology, bio-based manufacturing, bioenergy, bio-based environmental protection, and biotechnology services—all areas that generally fall within the scope of bioeconomy according to the scope defined in the EU.

According to one estimate, China's bioeconomy turnover amounted to EUR 2260 billion (RMB 17.64 trillion) in 2022, (Jiang, 2022). Therefore, regardless of the definitions, China has definitely recognized the bioeconomy as a priority area and contributor to the country's economy and this priority's importance has grown over the years. By the end of the 13th Five-Year Plan (2020), the output value of China's core biotechnology industries, such as biomedicine, biomanufacturing, bio-breeding, bio-energy, and bio-environmental protection, has reached nearly EUR 641 billion (RMB 5 trillion), and the revenue from the biotechnology and health-related industries has exceeded (RMB 10 trillion) (Jiang, 2022).

In May 2022, the National Development and Reform Commission (NDRC) issued the "14th Five-Year Plan for Bioeconomic Development", establishing a national biotechnology framework to boost the bio-economy during the next five years (2021-2025) and with stage goals until 2035 (NDRC, 2022). The plan aims to help meet rising domestic demand for healthcare and better lives, foster high-quality economic development, prevent and control biosecurity risks, and modernize China's system and capacity for governance (NDRC, 2022). The plan focuses on four areas for bio-economic development: bio-agriculture, biomanufacturing, biomedicine, and bio-security (Zhang et al., 2022). It defines three pathways to improve bioeconomy: technological innovation, industrialization, and policy support. According to an assessment by a service report for the US agricultural ministry, "few specifics are provided on how objectives will be achieved. Instead, the plan focuses on broad goals and outcomes" (NDRC, 2022, p.2). In general, China is aiming to modernize the domains involved in bioeconomy on all levels (e.g. institutional, operative and administrative. This process includes structural interventions in creating a modern ecosystem and

integrating the industrial sector, promoting innovation, green development, and exploring all sources of intelligence. However, when it comes to the governance structures, they seem to be aligned to the entire functioning system of China and the country is still lacking flexibility and enough openness.

### 2.1.3 Japan

Japan has a long history of support for the production and industrial use of biomass. Besides that, the country has established a very strong commercialization platform in the domain of life sciences. There is an impressive turnover in various sectors and ambitious goals of the Japanese Government to reach by 2030 the following targets:

- High-performance biomaterials, bioplastics (USD 485 billion);
- Sustainable primary production systems (USD 15.5 billion);
- Large-scale wood-based construction (USD 9 billion);
- Lifestyle-related healthcare improvement (USD 300 billion);
- Bio pharmacy, regenerative medicine, cell therapy, and gene therapy (USD 30 billion).

Also, the whole structure further involves data infrastructure, policy development, and systems maintenance. In 2019, for example, the Government of Japan funded roughly US\$56 million to promote bio-manufacturing technologies, including the demonstration and examination of bio-manufacturing data linkages.

Based on the above, and recognizing the importance of the Institutionalization of these activities, Japan published its first Bioeconomy Strategy in 2019. This strategy was updated one year later, having a focus on biotechnology and the exploration of biological data. This direction was partially induced by the situations created by the coronavirus pandemic, dictating the policy makers to focus on developing measures against future public health crises and building efficient supply chains.

In general, the strategy covers multiple sectors, including agriculture, industry, health, and medicine. Five basic policies guide the Japanese strategy:

- Development of targeted market areas, roadmaps, and sustained commitment;
- Integration of biology with digital technologies;
- Promotion as an international hub;
- Coordination and enhancement of international strategies (e.g., standards development, trade policies);
- Responding to ethical, legal, and social implications (Congressional Research Service, 2022, p.29).

According to the strategy, these policies reflect knowledge gained from previous efforts.

There is a wide spectrum of market areas where the strategy focuses and those are.

- High-performance biomaterials
- Bioplastics
- A sustainable primary production system
- Organic waste and wastewater treatment
- Health care for lifestyle improvement, functional foods, and digital health
- Industries related to biopharmaceuticals, regenerative medicine, cell therapy, and gene therapy
- Bio-foundries, including bio-production of food products
- Large-scale construction using wood and smart forestry

Responsible for the implementation of the strategy is a “Bioeconomy Taskforce”, composed of the heads of various innovation-related ministries and agencies. The actions of this body include the implementation, monitoring, and evaluation of the Bioeconomy strategy. Additionally, multiple agencies and offices are to provide funding and other support.

The implementation is also based on close collaboration with existing global bio-community hubs to combine leading research environments with established commercialization systems – and expects increased overseas investments and development of social systems that will attract talented human and other resources.

#### 2.1.4 Malaysia

Malaysia was one of the first countries in Asia (and even among the very first in the whole world to adopt a National Bioeconomy Policy (NBP). It was the year 2005 when the Malaysian Government recognizing that Bioeconomy is a key driver for economic and social development, established the NBP focusing on the development of three important sectors: Healthcare, Agriculture, and Industrial Manufacturing. The implementation of the NBP was planned in three phases:

- Phase I Capacity Building (2005-2010),
- Phase II Science to Business (2011-2015), and
- Phase III Developing Global Business (2016-2020).

The final aim was the enabling of an eco-system throughout the scientific, academic, and business communities in the country.

The successful implementation of the NBP led into the adoption of the NBP 2.0, which was launched in September 2022 and has three main pillars towards the year 2030. Those are: (1) Agricultural Biotechnology and Food Security, (2) Healthcare and wellbeing, and (3) Industrialization and Circular Economy. The Malaysian ambition is to be transformed from a technology-user to a high-technology innovator country. For the achievement of this ambitious goal, specific measures have been adopted such as: Emphasizing the global perspective of the companies, attracting world-class researchers, creating bio-innovation firms with unicorn status, and more.

#### 2.1.5 Reflections on international bioeconomy strategies

It is evident that each bioeconomy strategy comprises priorities and particularities of a respective country, but also reflects its political orientation, societal dynamics, and economic strength, by extending into the cultural background and specific attitudes.

It is therefore important to consider the relations of the EU bioeconomy strategies versus the above introduced global policies and strategies under this wide perspective, to better understand and compare different bioeconomy strategies and how do they relate to the situation in the EU.

The parameters to be taken into account in such comparison are: (1) The specific social and political interactions with the EU at all levels, including diplomatic implications and geopolitical dynamics; (2) The economic and financial aspects on a bilateral basis and globally; (3) The overall legislative frame and the existing regulatory specificities, especially in matters such as diversity, environmental protection, climate mitigation, etc.; (4) The level of technology and science, the existing infrastructures and the level of competitiveness resulting from it; (5) The choice of priorities and classification of values; and (6) Local attitudes, ethics, customs, and the whole cultural background.

Based on the above, we highlight some conflicting areas which possibly can affect the EU goals based on the international situation and global competitors, as described above.

- **Inclusion of biomedical and pharma business in the bioeconomy frame.** Unlike in the EU, the bioeconomy strategies in the US, China, and other countries comprise these sectors into the overall bioeconomy business. It is obvious that such inclusion in Europe would affect tremendously the currently calculated turnover but also would re-orientate the funding priorities, investments, alliances, etc.
- **Applicability of the bioeconomy strategy.** Unlike other countries having a widely applicable strategy in the whole state, in the EU, besides the European Strategy, there exist also National Strategies in various member states (MSs). In some, also Regional Strategies exist, operating rather independently under the National ones. While such regional level strategies may help to mobilize commitment and develop specific actions to realize regional potentials, there is also the risk of inconsistencies in policy-making and mixed signals to stakeholders.
- **Strategy adoption vs strategy implementation.** A lateral case of the above issue is the level of implementation of the Bioeconomy strategy in various MSs of the EU. In order for a strategy to be accurately implemented, an adoption from the social and political systems is required, together with a complete integration into the existing state mechanisms. This was not always the case in various EU states.
- **Establishment of the strategy.** In some countries (e.g., China) the strategy is designed and implemented in a top-down approach, while in other countries it is a bottom-up procedure, such as the EU. This is of course a result of the whole socio-political culture of the country. However, it also creates significant differences in the implementation and applicability levels. Further on this issue, it is also important for the Institution responsible for the strategy. For instance, in the US two different strategies exist: one elaborated and adopted by Congress and one prepared by a committee of experts and adopted by the White House. These kinds of discrepancies often are confusing. It is also important to mention the presence of strong lobbying practices in the American political scene, which is also partly applicable in the EU. Therefore, among the aims of these strategies might be topics beneficial for specific groups.
- **Applicability of the strategy.** Each strategy should be accompanied by a concrete implementation plan, which sets time frames, priorities and specific actions. In the EU, the adoption of the European Green Deal, the alignment with the SDGs as well as the Action Plan include also the implementation plan. However, this is not the case in other global regions.

## 2.2 Intergovernmental organizations and working groups in the bioeconomy

The issue of mutual learning from national approaches to the bioeconomy as well as strategic cooperation to address the multinational potential and challenges that the bioeconomy faces is addressed by multinational bioeconomic fora. In the following, a selection of key institutionalized international fora or working groups is presented concerning their role, goals and activities in the bioeconomy.

### 2.2.1 OECD

The Organisation for Economic Co-operation and Development (OECD) took up the topic of bioeconomy in the mid-2000s. The Working Party on Biotechnology, Nanotechnology and Converging Technologies (BNCT) consists of representatives from all OECD member states who focus among others on bioeconomy and sustainability solutions. It aims to contribute to original policy analysis and messages to the global community, to convene key stakeholders in the field, and to make proposals to policy makers. In 2009, the OECD's white paper: The Bioeconomy to

2030: Designing a Policy Agenda, that focussed on biotechnological applications in primary production, health, and industry and considered bioeconomy to be “the set of economic activities relating to the invention, development production and use of biological products and processes” was released (OECD, 2009).

Among others, the OECD highlighted synergies for the blue economy (OECD, 2016), which can be generated and captured through offshore platforms that also host renewable energy equipment. Since then, various global workshops and studies concerning various key topics regarding the bioeconomy, including sustainability measurement, policies and technological and industrial development, as well as technology assessment, have been published (OECD, 2023).

### 2.2.2 FAO

The FAO with the Strategic Framework 2022–31 (FAO, 2021) became the first UN entity to make bioeconomy a strategic priority. The FAO aims to provide “policy guidance and technical support to assist policy makers in establishing and implementing national and regional strategies, action plans, and programmes to develop a sustainable and circular bioeconomy in line with the Sustainable Development Goals, the Paris Agreement and other Multilateral Environmental Agreements” (‘FAO’s work for a sustainable and circular bioeconomy’, 2023).

An important setup for the work of the FAO in the Bioeconomy is the International Sustainable Bioeconomy Working Group (ISBWG), which is a multi-stakeholder expert group that serves as an informal platform for knowledge – and experience – sharing concerning sustainable and circular bioeconomy and, inter alia, acts as an advisory body to FAO’s bioeconomy programme. The ISBWG has a round around 35 members from all five continents and they differ in their background, from policy to research, private sector, civil society and international organizations (‘International Sustainable Bioeconomy Working Group’, 2023).

The FAO facilitates global policy discussions around the sustainability of bioeconomy innovations, including on topics such as microbiome science, alternative proteins, biopesticides, biofertilizers, biotechnology-based plastics and other bio-materials, including bio-vaccines, waste reduction, and biomass re-use, but also on aspects such as sustainability. Regarding the latter the FAO conducted global analysis and reports that currently more than 60 countries and regions (and growing) have bioeconomy and bioscience-related strategies (FAO, 2022); this includes countries in most regions globally and while no bioeconomy strategy is the same, each one includes elements relating to sustainability and climate action. Many countries are mentioning and including bioeconomy practices as part of their agricultural mitigation (Crumpler et al., 2021) and adaptation strategies in their new or updated Nationally Determined Contributions (NDCs).

The FAO states that 91 out of 148 countries (61%) explicitly referred to soil organic carbon measures, many of which indicate bioeconomy practices such as soil organic amendments or integrated soil fertility management as mitigation and/or adaptation means (FAO, 2022).

### 2.2.3 World Bioeconomy Forum

The World Bioeconomy Forum is a global platform for exchange between bioeconomy stakeholders, for the communication of strategies or for sharing business ideas and opportunities with decision makers, industry leaders or civil society organizations. It is built on the vision to become a paramount element in the promotion and facilitation of bio-based innovations for the replacement of non-renewable, fossil-based industries. Activities of the high-level global forum consist of four different pillars, which serve also as evaluation criteria for the status of the circular bioeconomy:



1. The Bioeconomy: People, Planet, Policies;
2. Global Leaders and the Financial World;
3. Bioproducts Around Us;
4. Looking to the Future.

The first pillar emphasizes the role of bioeconomies to be strongly enhanced in global trade policy frames, including coherent policy frameworks in international organizations. Furthermore, the first pillar aims to support and encourage societies and governments to convey strategies towards implementation stage with concrete and accountable action plans. Throughout the second pillar, the forum wants to foster the linkage between the bioeconomy and the financial world through diversifying financial vehicles on nature-based investments for example. Whereas the third pillar encompasses all innovative bioproduct applications, serving as alternatives to fossil-based products, the last pillar pronounces the circular bioeconomy as an additional policy tool in climate change mitigation and voluntary carbon markets (VCM) with carbon credits applied for bio-based products.

As an international platform, the World Bioeconomy Forum operates through different measures, such as events, information channels and engagement or through influencing policy makers. For instance, the Forum organizes regular round tables, which discuss recent developments of the circular bioeconomy with different stakeholders. The platform is also providing a comprehensive platform for engaging, collaborating and sharing knowledge with stakeholders about news, issues and events. Regularly policy makers are invited to take part in events of the forum and to communicate bioeconomy agendas and inputs on regulatory framing. Moreover, the World Bioeconomy Forum has a high-level advisory board with renowned experts on global bioeconomy developments. The advisory board is regularly advising the forum and providing recommendations.

### **Concluding remarks**

The above described international organizations have each a unique role to play in advancing bioeconomy and their roles and activities are highly complementary. The OECD is the first one who recognized the importance of bioeconomy, took up the topic already at the beginning of 2000s, and has thereafter carried on work regarding bioeconomy policy development via various working groups. The FAO entered the scene somewhat later, but as part of the world's largest intergovernmental organization, it has since then played a crucial role in making bioeconomy a strategic importance to the entire 193 UN member states across five continents. The World Bioeconomy Forum has more bottom-up approach compared to FAO and OECD, and has its main strength in creating legitimacy for bioeconomy by reaching out to the wide network of different stakeholders, which is necessary to complement the policy work done by other international organizations working on bioeconomy.

## 3 EU state of play in the bioeconomy

The following chapter is focused on giving an EU level overview of the current status quo of the bioeconomy. It presents information in terms of key sectors and countries in terms of primary production and use of biomass and how the key indicators of the innovation ecosystems are performing (i.e., R&D, public and private funding, patents and publications). Furthermore, chapter 3.1.3 elaborates on the use of biomass and the current status of biorefineries and eventually chapter 3.1.4 provides information on how the bioeconomy sector contributes to the EU economy in general and what main developments are foreseen for the upcoming years.

For all dimensions, we present indicators for the EU-27 status quo and where available the development over time and the distribution across EU member states. For very few indicators, we differentiate between so called macro-regions (MRs), which are analysed more in-depth in Deliverable 1.4 of this project. The MRs are the Baltic-Sea region (EE, LV, LT, FI, SE), Central & Eastern Europe (BG, CZ, HR, HU, PL, RO, SI, SK), Western Europe (BE, FR, DE, LUX, NL, IE, AT), and Southern Europe (ES, PT, MLT, IT, CYP, GR).

### 3.1 Primary Production

Agriculture, forestry, fisheries and aquaculture are the sectors of primary production of the European bioeconomy. Next to food and feed, these sectors provide the biomass, which can be converted into different products, (bio)energy and a variety of different materials and chemicals (Park & Grundmann, 2022). Biomass production subsector has a key importance in different dimensions, i.e. it is considered to have positive implications for mitigating climate change and by substituting fossil-based energy production.

In this chapter, status quo and key developments of biomass production from primary production systems in the EU-27 will be described. Figure 1 below shows the total biomass production from primary production systems from 2009 until 2017 in the EU.

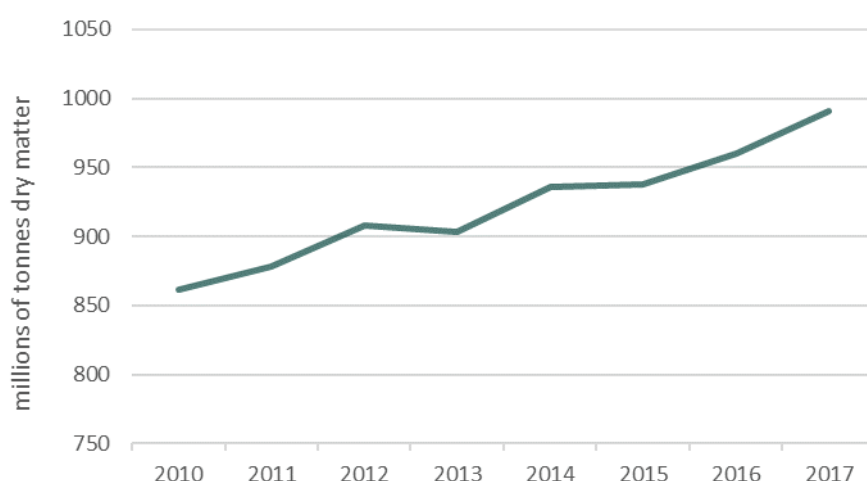


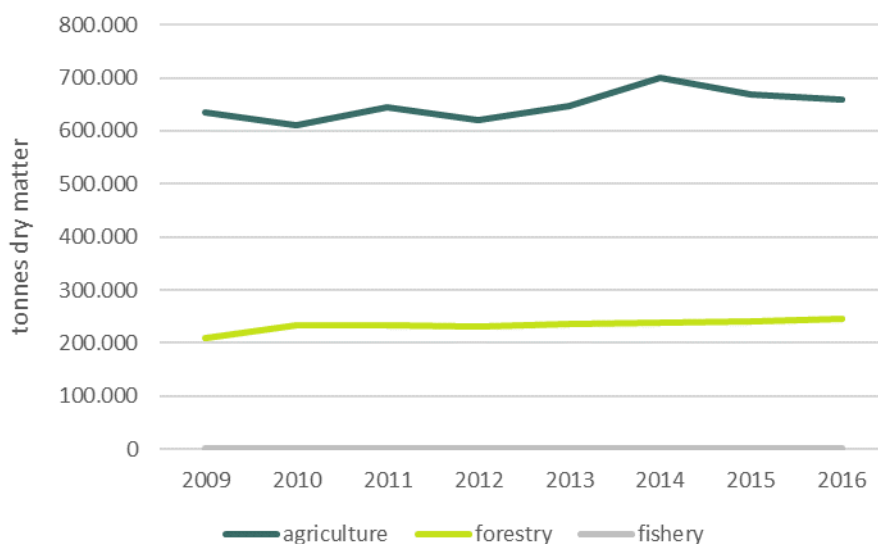
Figure 1: Biomass production in EU (EU-27).

Source: European Commission, Joint Research Centre (2023b)

Figure 1 illustrates that the total biomass production has increased constantly within the time duration. Whereas biomass production started with approximately 0.84 billion tonnes per dry matter in 2009, it reached its peak in 2017 with almost 0.96 billion tonnes per (dry matter) (European Commission, Joint Research Centre, 2023c). The latest data from 2017 show that the total biomass supply in the EU accounted for 1.2 billion tonnes of dry matter. It accounts for 10% of around 12 billion tonnes global biomass production (European Commission, 2022b; Popp et al., 2021).

As illustrated in Figure 2 the share of biomass production of the main primary production sectors in the EU has remained stable over the last decade and is expected to continue so. The agricultural sector is by far the largest biomass provider in Europe with more than 70%, out of this, crops represented almost half, i.e., 47%, followed by marginal contribution of grazed biomass and crop residues, 14% in total. The agricultural sector is followed by a significantly smaller contribution by the forestry sector (i.e., 26%), out of which primary woody biomass constituted 22% together with different co- and by-products (e.g., wood pellets) at 9% and post-consumer wood with 2%. The biomass provided by the aquatic sector is limited compared to other primary production sectors, remaining around 2 million tons, which is less than 1% of the total biomass production (Popp et al., 2021).

However, the low share of total biomass may underestimate the overall importance of the marine based sectors in the bioeconomy, because of algae production, which is a valuable resource for the EU's food and chemical industry. The demand for algae biomass has been increasing over the last decade and is expected to continue as novel algae-based applications are developed, such as feed and food supplements, nutraceuticals, pharmaceuticals, third-generation biofuels and bioremediation, to name a few (European Commission, Joint Research Centre, 2018).



*Figure 2: Biomass production from primary production systems in EU per sector.*

Source: 'EU Bioeconomy Monitoring System' (2023)

In 2017 the EU imported only around 5-6% of biomass, the weight of dry matter of around 0.2 billion tonnes, stemming from agriculture (European Commission, 2022a). The trade balances of animal products (feed equivalent), solid wood products and bioenergy were positive. Furthermore,



the EU was a net importer of processed products (biomass equivalent) plant-based food, wood pulp, wood pellets and round wood ('EU Biomass Flows', 2017; European Commission, Joint Research Centre, 2017b; Popp et al., 2021). The biggest source of biomass in fishery and aquaculture has been imported fish and seafood, which are followed by captured fisheries (European Commission, Joint Research Centre, 2023a).

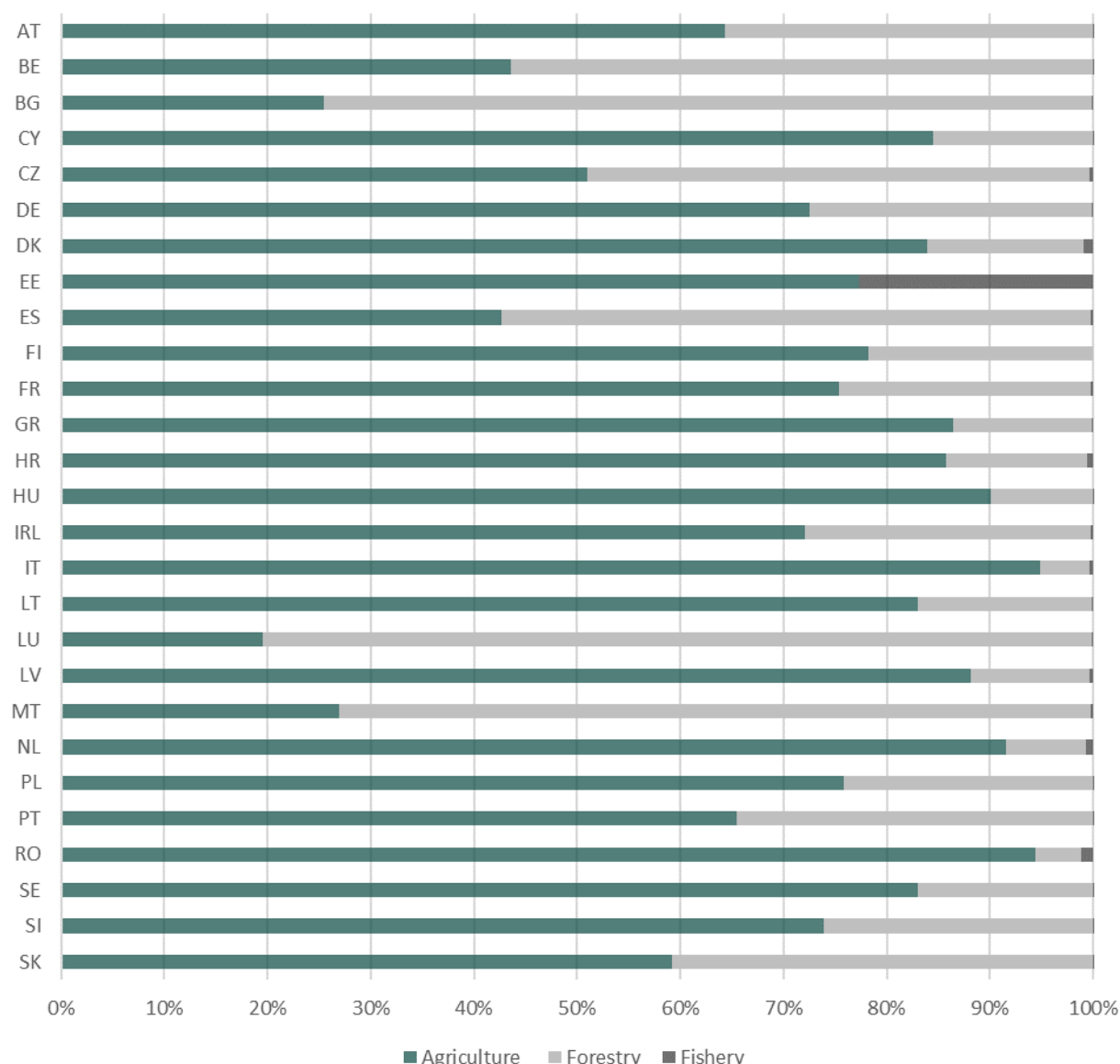
Out of the total biomass used in the EU, the largest share of agricultural biomass went to feed, bedding and animal-based food (49%), plant-based food (10%), liquid biofuels feedstocks (4%) and energy (4%). Grazed biomass and harvested residues are also used as feed and bedding. Wood biomass was used as solid wood product and wood pulp for biomaterials (20%) and as heat and power for bioenergy production (13%). The energy and pellet use of wood biomass has been steadily increasing in the last two decades) (European Commission, Joint Research Centre, 2017b; Popp et al., 2021).

According to the data from the Joint Research Center (JRC) (European Commission, Joint Research Centre, 2023a), the overall biomass use in the EU has increased by around 5.6% between 1010 and 2017. Most of the increase in the overall biomass uses was due to rising demand for bioenergy (+28 million tons of dry matter (Mtdm)), followed by increased demand for bio-based materials (+17 Mtdm). The use of biomass for bioenergy has shown a steady growth of about 15% between the counted periods. The use of biomass for producing materials has increased overall by 6.6% (European Commission, 2022a).

Production from EU primary production systems on a country level based on the data from the JRC varies greatly ('EU Biomass Flows', 2017). Based on the data from 2016, primary production in Europe is dominated by agriculture and for half of the EU-27 countries, agriculture constitutes more than 75% of the primary production. The countries with the highest share are scattered all over Europe with Greece (94.8%), Cyprus (94.45%), Denmark (91.5%), Hungary (90.12%), followed by Spain, Italy, Ireland, Romania, the Netherlands, Bulgaria and France where agriculture presents between 80-90% of the primary production.

Forestry holds a second position and is mostly present in the northern European countries. More than 50% of country level primary production comes from forestry only in 5 EU countries, i.e., Finland (80.3%), Sweden (74.5%), Estonia (72.83%), Latvia (57%) and Slovenia (56%). In Portugal and Austria, forestry is also a significant contributor to primary production (i.e., 48 and 41%), in all the other EU-27 countries the role of the sector is marginal.

In fisheries the EU covers 2% of global production ('European Market Observatory for Fisheries and Aquaculture', n.d.) and in general plays a marginal role in the EU-27 primary production, having less than 1% of the market share in the majority of the countries with exception of Malta, where fisheries present 22.65% of the countries primary production next to agriculture with more than 77%. Spain, Denmark and France are the largest producers in terms of volume in the EU, even though fisheries presents only a marginal share of their primary production (i.e. 0.4%, 0.69%, and 0.12% accordingly) ('Fisheries and Aquaculture Production', n.d.).



*Figure 3: Biomass production in EU from primary production systems (2016).*

*Source: Fraunhofer ISI calculations*

### 3.2 Innovation indicators

Bioeconomy is considered an early-stage industry which needs innovation in technologies, processes, products and behaviour to increase its value as well as sustainability (Popescu, 2014; Philp, 2018; Schütte, 2018). Bioeconomy innovations have certain specificities that partly distinguish them from other innovations: they are interdisciplinary by nature, they are usually at a low level of technological readiness for their implementation, which implies requirements for research organizations and the production of new applicable R&D results (Aguilar et al., 2018; Bröring et al., 2017; Curran et al., 2010), as well as new ways of learning Bioeconomy innovations

are expected to support the development of bio-based markets through the creation of sectoral linkages and input symbiosis (waste from one sector becomes input to another sector). The measurement of innovations in the bioeconomy is a challenging task, not only because of the named specific properties, but also because of the high heterogeneity inside the bioeconomy with high differences in type of innovation (e.g., process vs product), relevant sector, disruptiveness or type of impact (Wydra et al., 2023).

The following sub-chapters provide insights based on a few selected relevant innovation indicators along the innovation chain.

### 3.2.1 Funding

The transition towards a sustainable bioeconomy requires innovation on many different levels, ranging from R&D and technologies, processes to final products as well as social innovations. Bioeconomy innovations are expected to support the development of bio-based markets through the creation of different intra- and cross-sectoral linkages and circularity. This also includes new value-added production opportunities that create new outputs or use new resources for established value chains (Philp, 2018). Experts therefore call for increased investments in R&D or policy incentives to increase the competitiveness of bioeconomy, as one of the most important drivers of the transformation to sustainable development (Philp, 2018).

On the EU level, Horizon 2020 and Horizon Europe are the key funding mechanisms to support R&D activities of bioeconomy in Europe. Based on the data available on CORDIS Dashboard, more than EUR 1.5 billion has been already allocated to different research projects within Horizon Europe funding programme since 2021 within Cluster 6<sup>2</sup>. On aggregate, six member states receive more than 70% of these EU funds led by Germany, Spain, Netherlands and France between EUR 195 and 153 million, followed by Italy (EUR 147 million), Belgium (EUR 128 million) and Greece (EUR 81 million). As illustrated in Figure 7 the same countries dominate also the overall funding received in Horizon Europe.

Attributed to macro-regions, 54% of Cluster 6 funding is received by Western Europe, 29% by Southern Europe, 11% to Baltic Sea and 6% to Central and Eastern Europe. The reasons for this are manifold, ranging from Central and Eastern European countries being traditionally focused on primary production and less so on R&D activities and already fixed long term collaboration activities between actors, where new project partners have difficulties in getting involved in the established research consortia.

However, when looking into funding received per inhabitant, we still see the dominance of Western Europe, but the leading positions belong to the countries with lower population, such as Finland, Cyprus, Denmark, Belgium (all more than EUR 10 per inhabitant), followed by Luxembourg, Ireland, the Netherlands and Greece between EUR 7 and 10 per inhabitant. The best performing Eastern Europe countries are Slovenia and Estonia (both EUR 6 per inhabitant), which are also population wise among the smallest countries in their category (Figure 5).

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<sup>2</sup> Cluster 6 in Horizon Europe includes: food, bioeconomy, natural resources, agriculture and environment.

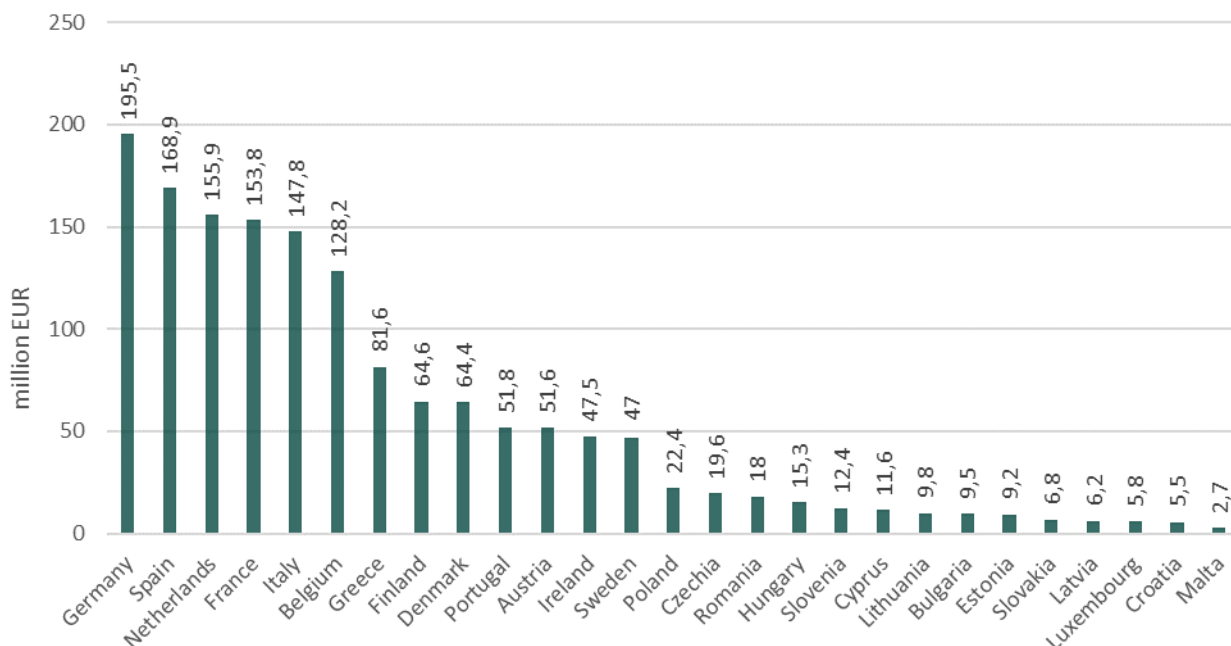


Figure 4: Horizon Europe funding per country in Cluster 6 (Status: September 2023).

Source: Fraunhofer own calculation based on CORDIS database

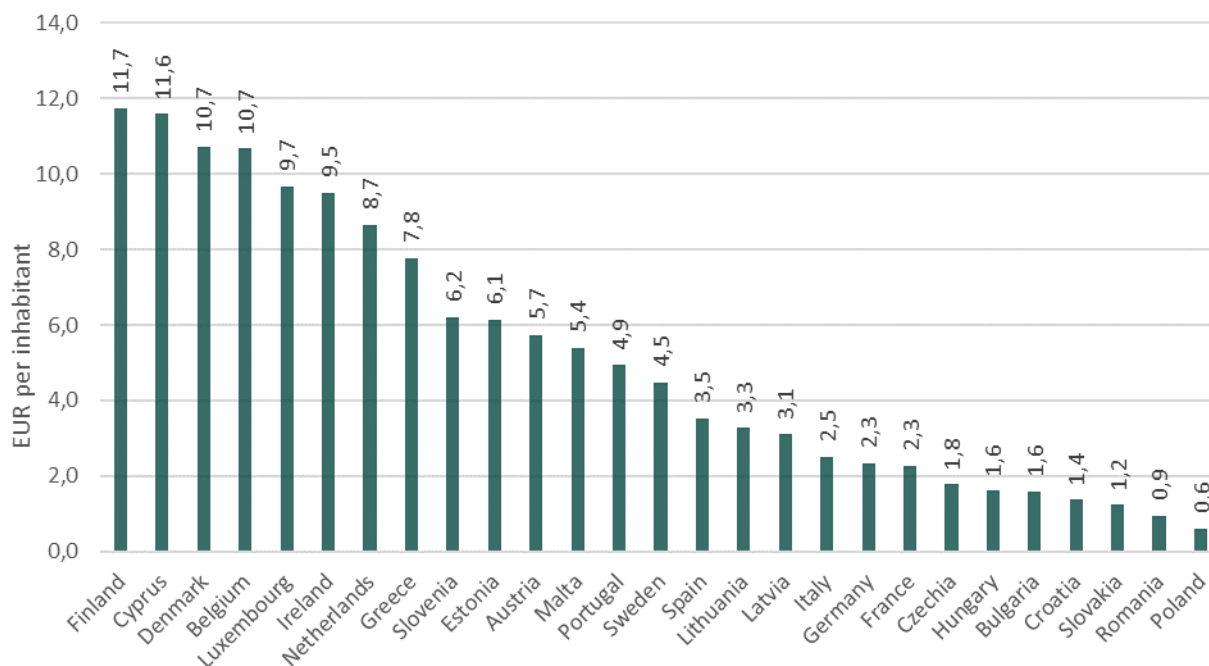
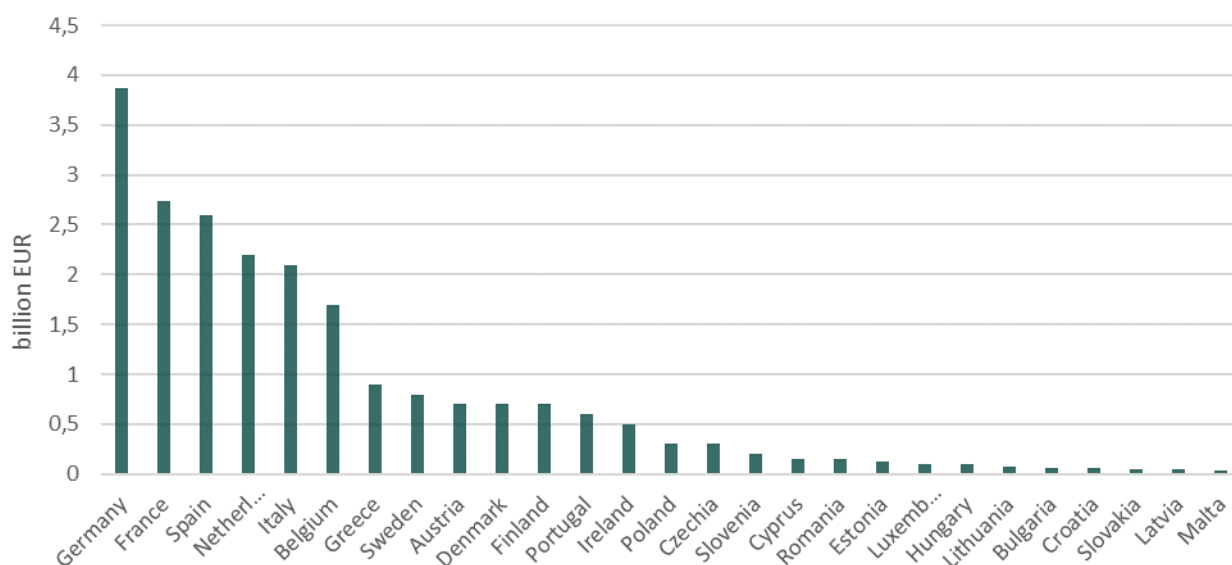


Figure 5: Horizon Europe funding in Cluster 6 per inhabitant (Status: September 2023).

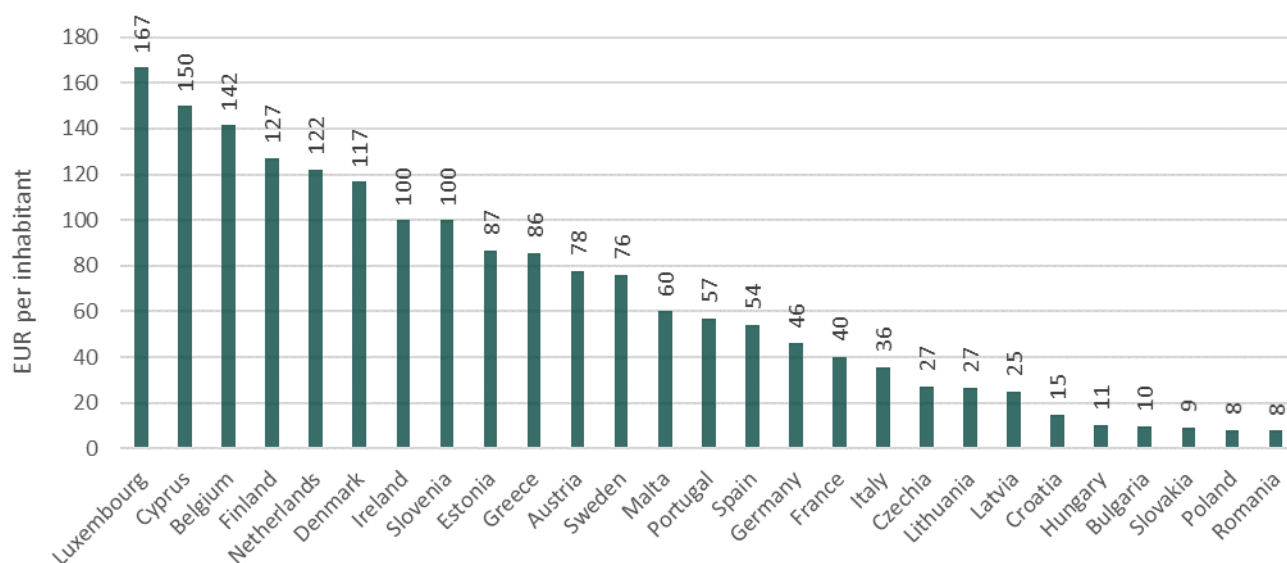
Source: Fraunhofer own calculation based on CORDIS database

When comparing the data on Cluster 6 with the overall funding under the Horizon Europe programme, we see very similar patterns. On aggregate, the same seven member states have received more than 70% of these EU funds led by Germany, Spain, Netherlands and France (Figure 7). Furthermore, when looking into overall funding under Horizon Europe, received per inhabitant, we see the dominance of the same Western European countries as in Cluster 6, with the leading positions belonging to the countries with lower population, such as Luxembourg, Cyprus, Belgium, Finland, the Netherlands and Denmark receiving all more than EUR 100 per inhabitant. This is more than ten times difference to the lowest performing East European countries, such as Bulgaria, Romania, Slovakia, Poland with less than EUR 10 per inhabitant (Figure 6).



*Figure 7: Total funding in Horizon Europe per member state (Status: September 2023)*

*Source: Fraunhofer ISI calculation based on CORDIS database*



**Figure 8: Total funding in horizon Europe in member states per inhabitant (Status: September 2023).**

*Source: Fraunhofer ISI calculation based on CORDIS database*

Furthermore, as illustrated in Figure 9 below, the scene is very similar regarding the funding by the CBE JU, where some Eastern European countries perform significantly better compared to Horizon Europe funding (i.e., Romania, Estonia), but from more than EUR 814 million, distributed by the CBE JU, again the majority has been granted to the same powerful bioeconomy countries as in Horizon Europe bioeconomy funding schemes. On aggregate, six member states receive more than 70% of these EU funds led by Spain, France and Italy between EUR 150 and 90 million, followed by the Netherlands (EUR 86 million), Germany (EUR 84 million) and Belgium (EUR 63 million). These results highlight that participation rates and the percentage of on bioeconomy directed research funding vary significantly between member states. The original member states still received times more research funding than the newer ones and differences in the national innovation capabilities across European countries remain a worrying issue. Attributed to macro-regions, 49% is received by Western Europe, 33% by Southern Europe, 12% to Baltic Sea and 6% to Central and Eastern Europe.

On the member state level, funding received per inhabitant, we see still dominance of the same countries as in Horizon Europe funding, with exemptions of Estonia and Latvia. In these cases, this cannot be attributed to a general trend, but rather is a result of one major project with high funding, that can significantly impact of the countries performance with small population (Figure 10).

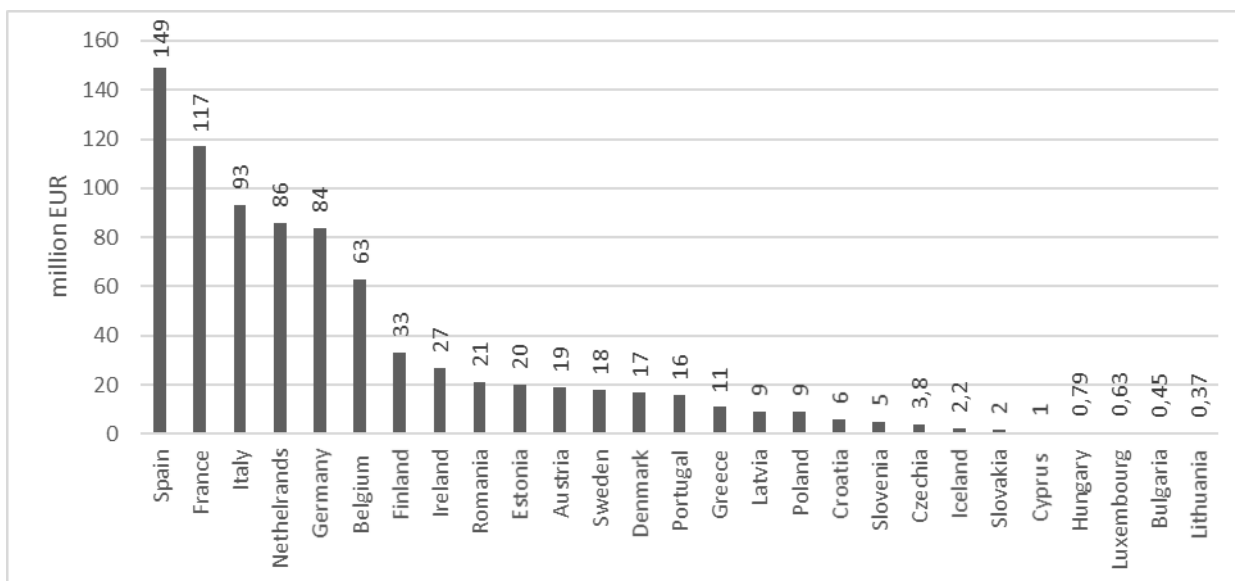


Figure 9: CBE JU funding in EU-27 (Status: September 2023)

Source: CBE JU Infographics (European Commission, 2022a)

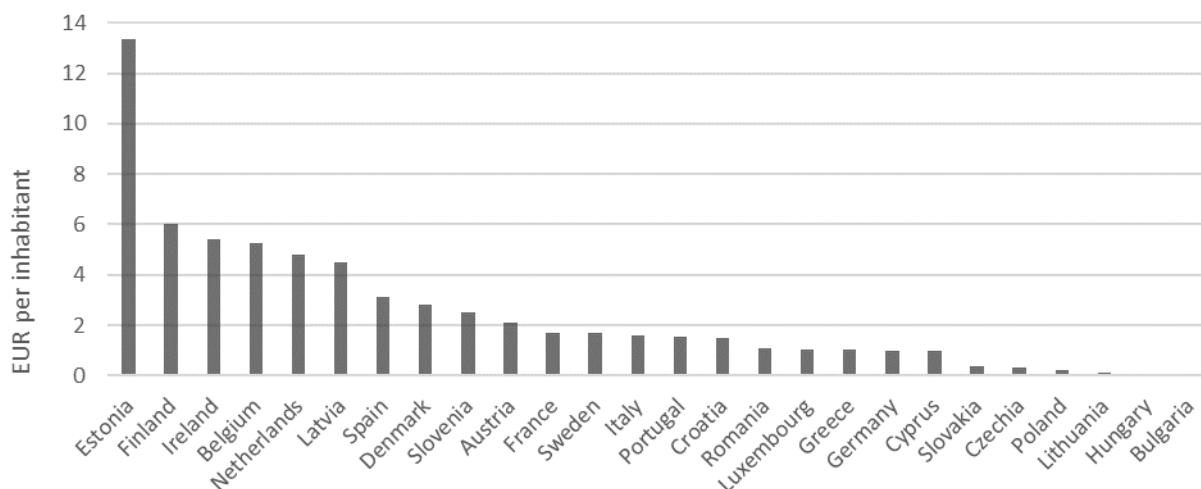


Figure 10: CBE JU funding received per inhabitant (Status: September 2023).

Source: CBE JU Infographics (European Commission, 2022a)

In terms of specific actor groups receiving CBE JU the data shows that SMEs are very highly represented and have received the most funding in the top 6 countries (Figure 10): Spain, France, Italy, the Netherlands and Germany. Out of the total 1055 beneficiaries of the CBE JU funding in the EU-27, 447 are SMEs (42%), 251 larger companies (24%), 261 academic institutions (25%) and 96 others (9%). This illustrates the presence of significant financial support for the SMEs in top performing bioeconomy countries of the EU-27.



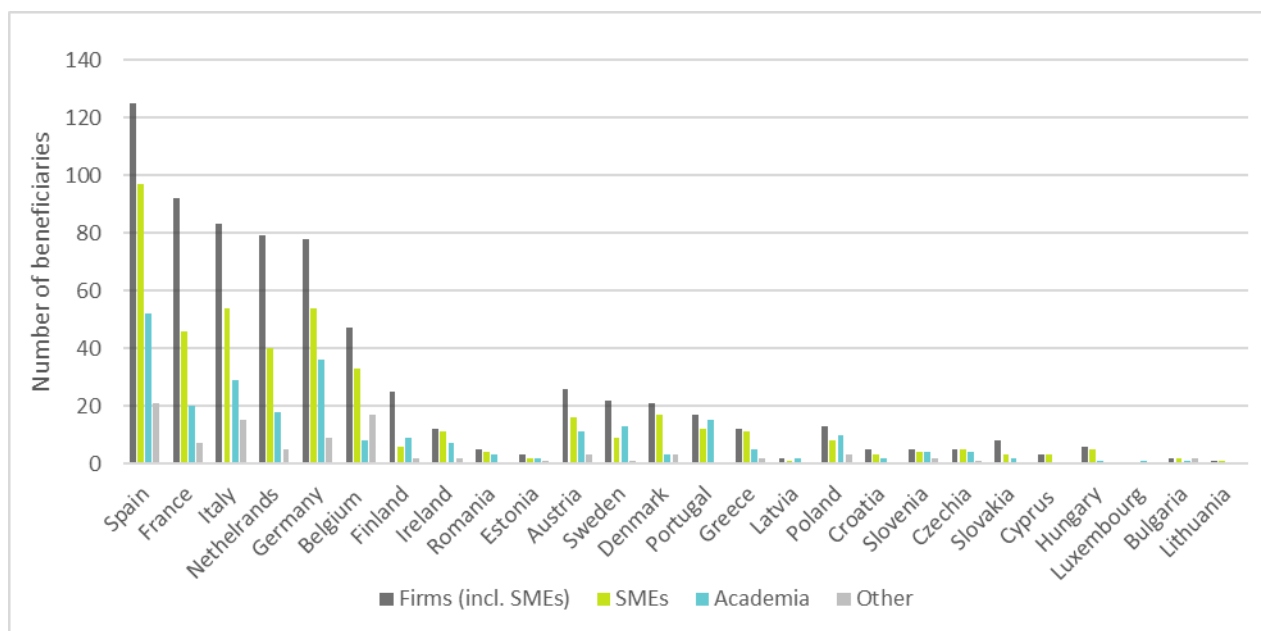


Figure 11: CBE JU funding in different EU countries per stakeholder group (Status: September 2023).

Source: CBE JU Infographics (European Commission, 2022a)

### 3.2.2 Patenting

Another important indicator to provide deeper insights into the field of EU bioeconomy and to measure its innovativeness is patent applications, as it brings along a great deal of new intellectual property (IP). Therefore, the patent data can be used as a source to identify the number of patents filled over time and how it compares to other competitive regions globally. Certain challenges are related to this, especially the crossover character of the bioeconomy, as it spreads over different sectors and industries and provides the application to various processes and products (Jeddeloh et al., 2022). Moreover, there are well-known limitations to using patents as an indicator of innovativeness as some innovations are not patentable and some other (patentable) market-relevant innovations are not patented. Nevertheless, as patent data are available in standardized form for most involved industries, are available on a global and national scale over the last decade, it enables to create further insights and analyse innovation activity across bioeconomy related industries.

While in 2011 only a small share of patent applications came from China, this ratio has been significantly changing due to the significant technological catch-up of Chinese bioeconomy companies, as it can be observed for other technology fields in a similar manner. This resulted in active patenting activities, increasing the patent applications 4-fold from 1000 to more than 4000 in 10 years of the Chinese companies.

This trend of increased patenting in China compared to a slight decrease of patents in other world regions can be explained by a very patenting supportive climate in China, as direct financial subsidies (in addition to tax breaks and other social benefits) are provided to the patent applicants, which is not sector specific but has definitely encouraged companies in the bioeconomy sector to invest in R&D and to file for patents that protect their intellectual property (Mangelson et al., 2020).



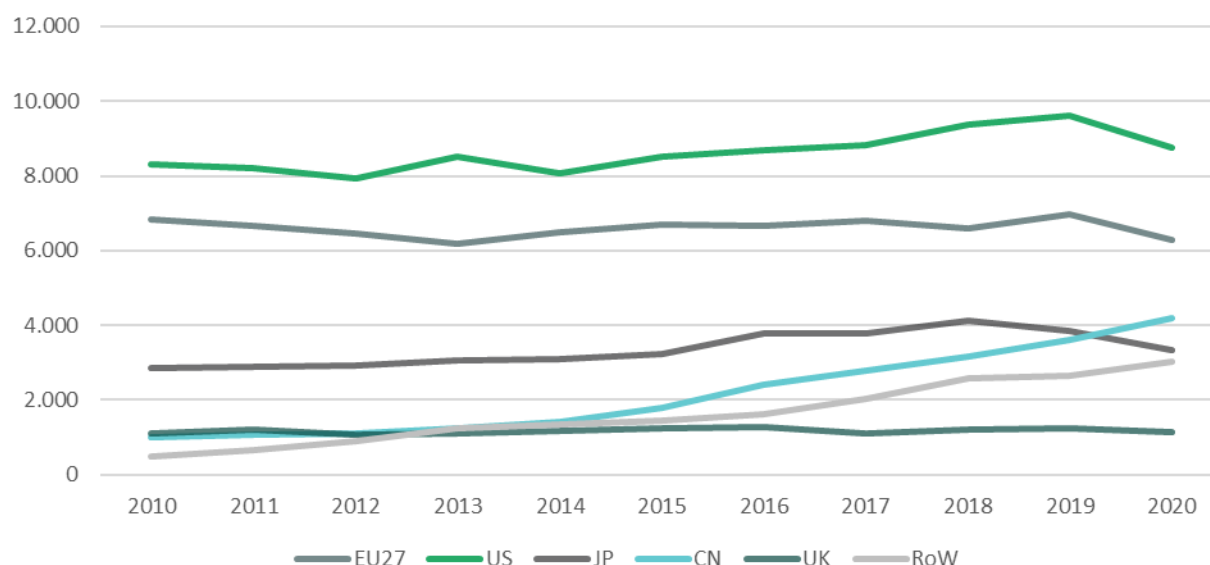


Figure 12: Trends of patent applications in the field of the bioeconomy in 2010-2020.

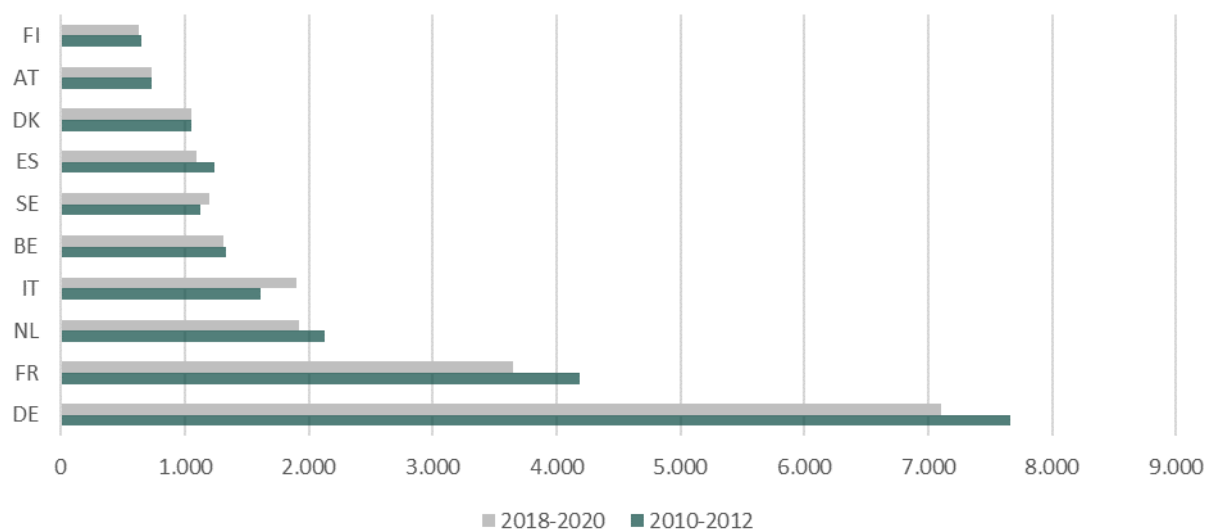
Source: Fraunhofer calculation, based on STN database

Although China is investing heavily in innovation and the total rate of patent applications has been steadily increasing since 2010, the patenting activities are still lower than in the EU-27 and the US across all the technology fields, related to bioeconomy. The European bioeconomy sector's patenting levels remain second after the US across all different technologies in the bioeconomy sector. Furthermore, despite the substantial dynamism in EU-27, the overall level of bioeconomy related patenting has remained constantly lower compared to the US ecosystem, when considering globally relevant patent applications and revealed technological advantage (RTA)<sup>3</sup> index. The latter provides an indication of the relative specialization of a given country in selected technological domains (compared to baseline) and is based on patent applications filed under the Patent Cooperation Treaty.

Zooming into the country level, we see that EU-27 patenting activities in the bioeconomy field are dominated by Germany and France. Nevertheless it is important to notice that for the major players, patenting activities have decreased between 2018-2020 compared to 2010-2020, which could be partly explained by the global economic slowdown caused by the Covid-19 pandemic, which has created a negative impact on innovation in many sectors of the EU economy. Figure 13 also illustrates that all the top ten countries with most patent applications over the last decade are from the Western-Europe, highlighting the great heterogeneity of the field in Europe between Eastern and Western European countries. The Central and Eastern Europe countries are involved in around 3% of the EU-27 bioeconomy patents between 2018 and 2020. This share remained rather constant in the last decade. Instead, the Western EU member states contribute to 75% of

<sup>3</sup> The revealed technological advantage index is defined as the share of an economy's patents in a particular technology field relative to the share of total patents in that economy. The value 1 indicates that the share in the technology field is equal to the total share.

the patents, Southern Europe to 16% and Baltic States to 21%. Please note that one patent can be submitted by actors from several EU member states.



*Figure 13: Trends of patent applications in the EU-27 among top patent applicants between 2010-2012 and 2018-2020.*

*Source: Fraunhofer ISI calculation*

When measuring the technological specialization to bioeconomy related technologies based on average relatedness compared to all patents of EU-27 and other global regions, it demonstrates that technological specialization has remained constant at around 1 in the EU-27 over the last ten years (Figure 14). Hence, bioeconomy patent level and development reflects the total patenting behaviour in the EU.

Whereas in the US, the specialization level is higher (between 1.2 and 1.6), and there has been a constant increase until 2019, followed by a slight decrease. In China, the specialization is significantly lower compared to the EU-27 and US, furthermore, like in Europe, the specialization has remained constant over the last years.

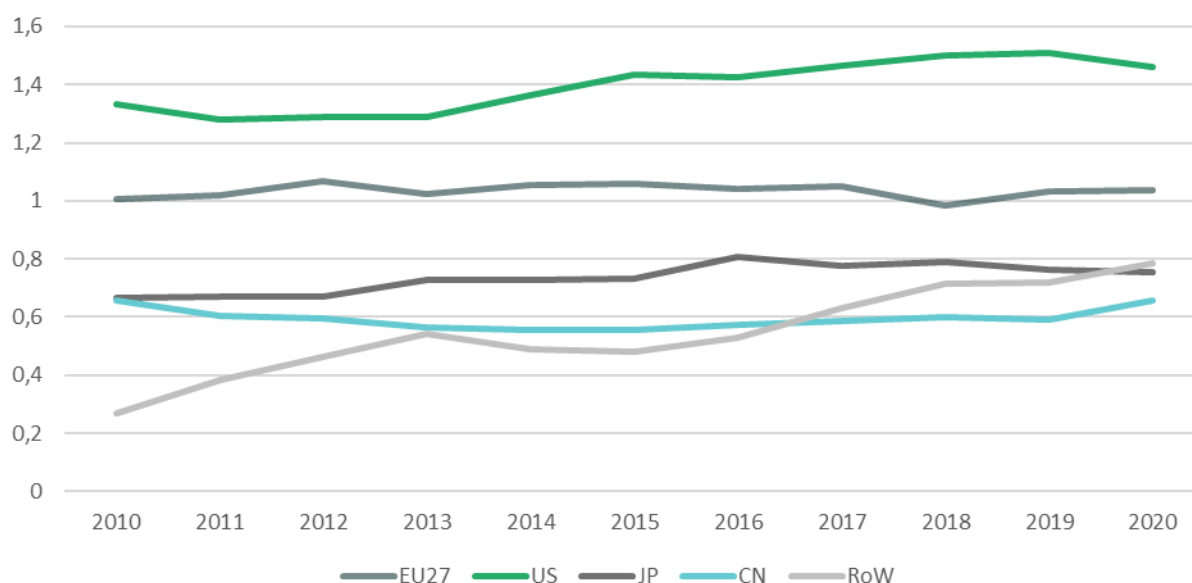


Figure 14: Share of bioeconomy patents of different world regions based on the RTA index.

Source: Patent database

Inside the EU-27 no clear picture for technology specialization emerges. The dominating patenting countries such as Germany, France or Italy have a specialization index close to 1, while smaller countries with rather few patents either show a rather high specialization on bioeconomy patents (e.g., Portugal, Cyprus) or low specialization (e.g., Romania, Malta).

### 3.2.3 Use of biomass and biorefineries

According to the JRC data from 2020, there are about 2,362 biomass processing facilities across the EU. Most of them are located in Germany and France, but interestingly Sweden ranks third and Finland ranks fifth. Accordingly, almost half of these facilities are located in Western Europe (49%), followed by Baltic states (24%), Southern (16%) and Central / Eastern Europe (11%). Most facilities produce pulp and paper (21.4%), followed by bio-based chemicals (19.9%), timber (18.5%), biomethane (14.3%), liquid biofuels (12.8%), starch and sugar (7.6%) and composites and fibers (5.5%). Figure 15 summarizes the absolute values, please note that some of the biomass producing units produce more than one product, hence to some extent biomass facilities are double-counted.

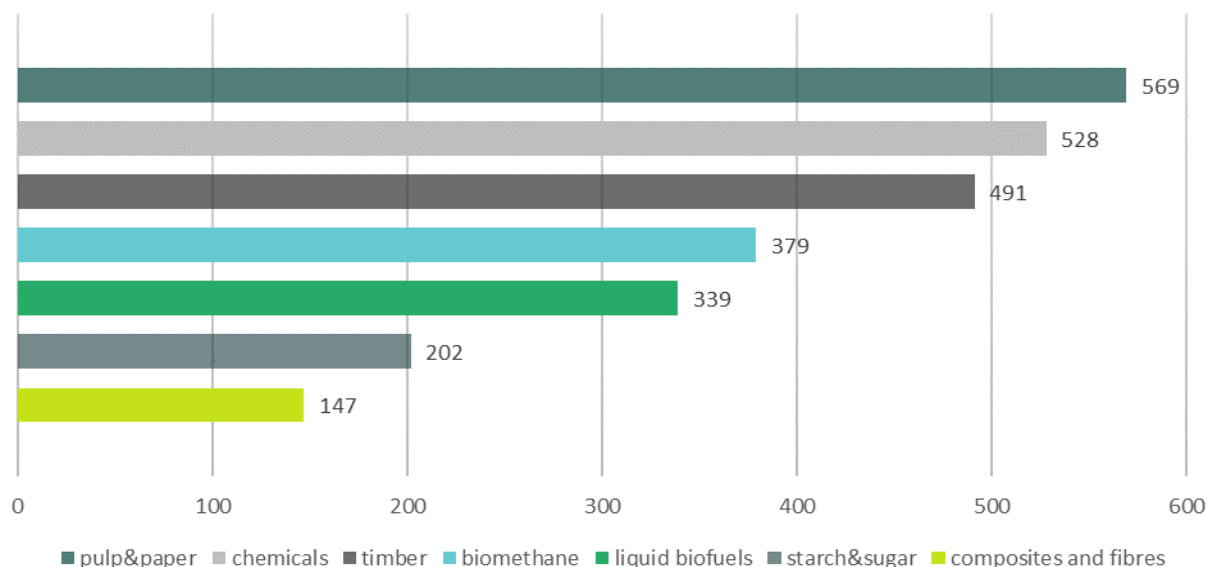


Figure 15: Bio-based industry facilities by product class in the EU (2020).

Source: European Commission, Joint Research Centre (2020)

The major feedstock sources are coming from forestry (47.9%) while 33.7% employ feedstock sourced from agriculture 33.7%), grasses and short-rotation coppices represent 9% of the total number of facilities, while waste (8%) and marine (1.4%) follow.

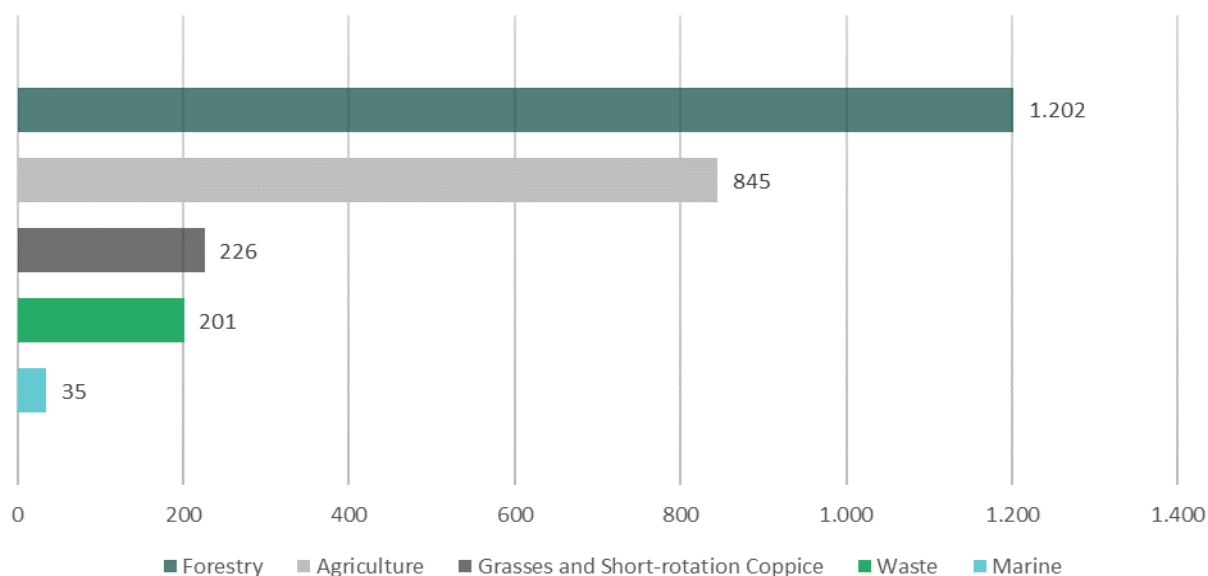


Figure 16: Bio-based industry facilities by feedstock origin in the EU (2020).

Source: European Commission, Joint Research Centre (2020)

### 3.3 Contribution of BE to EU Economies

While the former chapters show that many bioeconomy innovations are just evolving, the bioeconomy already contributes significantly to employment and value added in Europe

The goal of this sub-chapter is to assess the overall economic relevance of the bioeconomy, its development over time and to investigate, which sectors contribute significantly to bioeconomy activities in Europe. The data that has been used was extracted from the datasets, the JRC of the EU has provided. The respective time period that has been analysed spans from 2008 until 2019. We combine data for Nomenclature of Economic Activities (NACE) sectors to the four main aggregate sectors for ShapingBio, namely primary production, food and beverage, bio-based products, bio-based energy/fuels.

Figure 17 shows the number of persons employed per bioeconomy sector and in total from 2008 until 2019. Total employment in EU decreased slightly in the last years due to a reduction in the agricultural labor force. It reached 17.1 million total employments in the bioeconomy sectors in 2019 (8.2% of the whole total employment in Europe). Primary production, comprising agriculture, forestry and fishery, still employs most persons in the bioeconomy with bit less than 10 million persons. However, it was decreasing due to labour productivity improvements in the last years. Bio-based energy and fuels had the smallest amount of person employed, since these sectors are still not really developed in the European bioeconomy. Bio-based products sectors employ rather constantly around 3 million persons and present a share of 18% of the bioeconomy employment in 2020. Similar trends evolve for food and beverage with an employment of around 4.5 million person (share 27% of total bioeconomy employment in 2020).

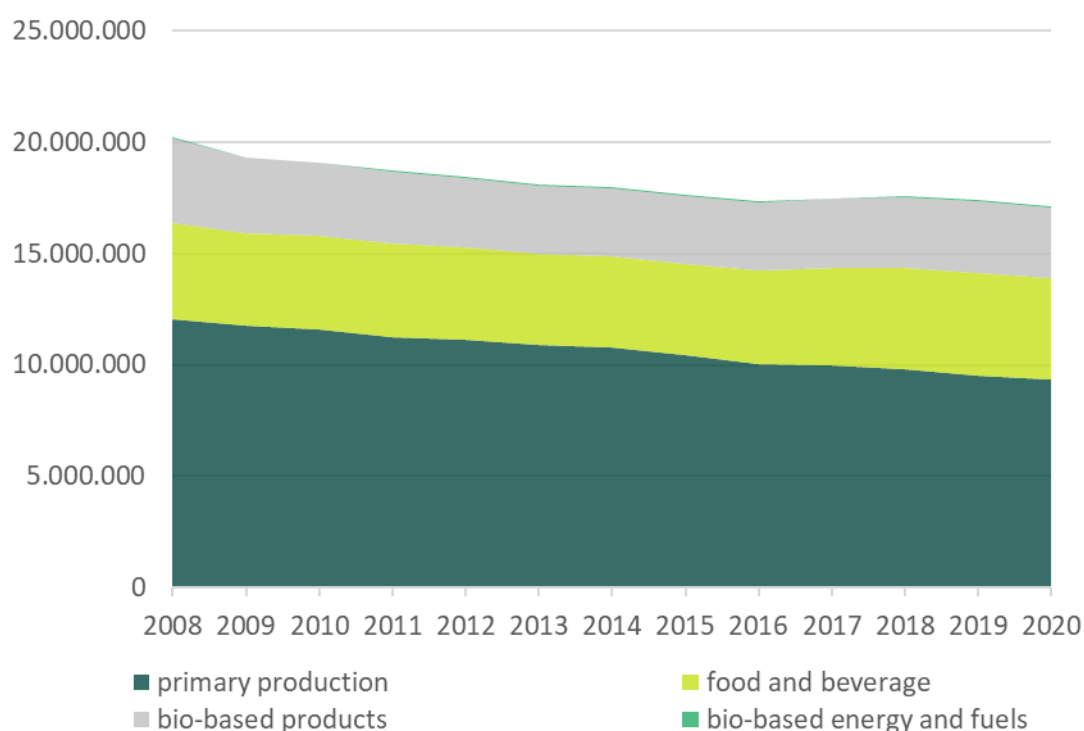


Figure 17: Persons employed between 2008 and 2020 in bioeconomy sectors.

Source: Fraunhofer analysis based on JRC data

Geographically, bioeconomy employment is falling in Central and Eastern Europe is falling (Figure 18), but it still presents the highest number of employees in the bioeconomy sectors. In 2020, Central and Eastern Europe made up approximately 39% of the total employment numbers with 6.6million persons employed, comprising more than one third of bioeconomy employment in the EU-27. While Western Europe amounts around 29% of the total employment in the bioeconomy sector (~5 million persons employed) and Southern region presents 26% (~4.6 million persons employed). For both macro-regions the numbers have been stable over the last decade. The Baltic Sea region employs the smallest, but also stable number of people.

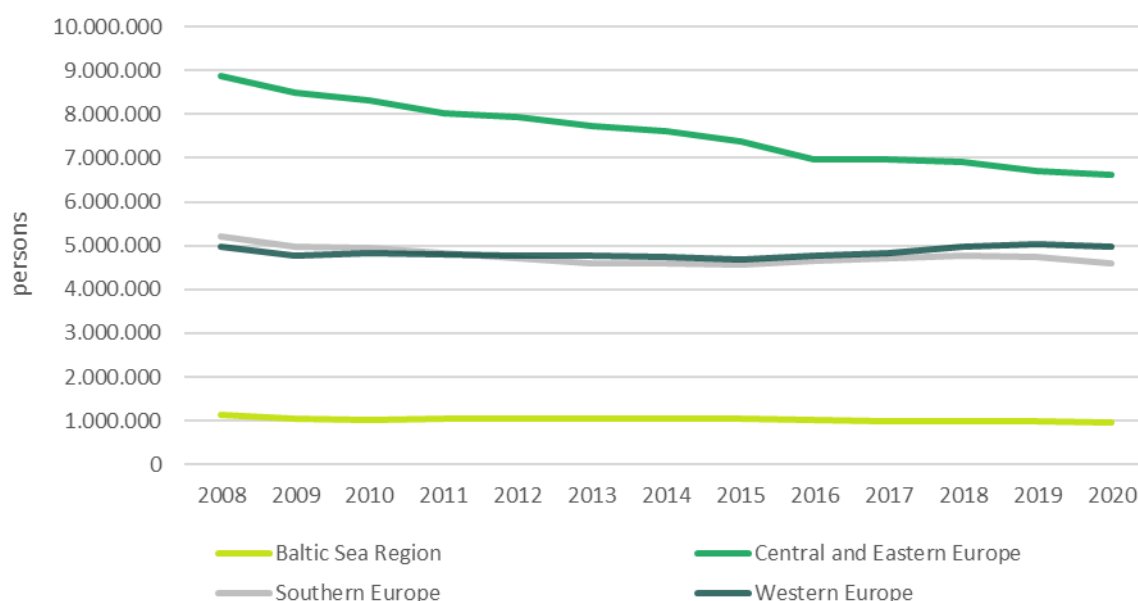
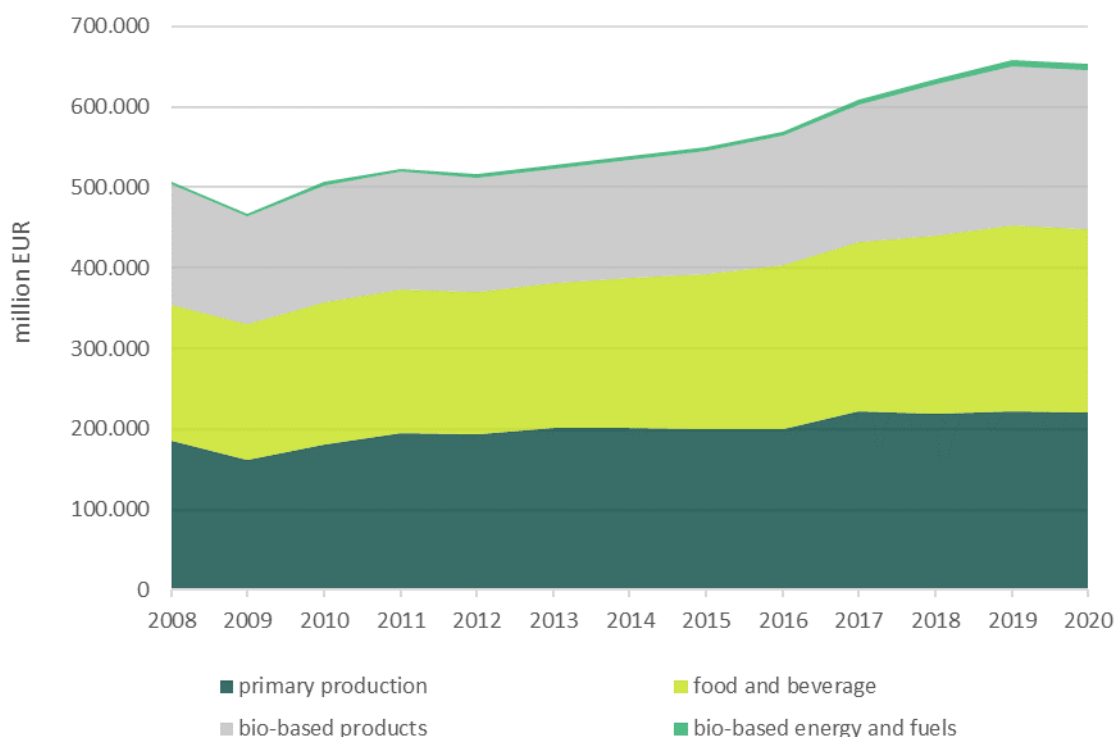


Figure 18: Employment trends in different EU regions<sup>4</sup>, 2008 – 2019.

Source: Fraunhofer analysis based on data from JRC

However while overall employment in the bioeconomy is declining, its contribution to value-added is increasing (Figure 19). Value added is defined as the gross income from operating activities after adjusting for operating subsidies and indirect taxes. Figure 16 shows the total value added of bioeconomy sectors in EU. In all analysed sectors value added have been significantly increased from 507 billion in 2008 and reached in total of 654 billion in 2019. This means an increase of 142 billion value added over the analysed period.

<sup>4</sup> Baltic-Sea region: EE, LV, LT,FI,SE; Central & Eastern Europe: BG, CZ, HR, HU, PL, RO, SI, SK; Western Europe: BE, FR, DE, LUX, NL, IE, AT; Southern Europe: ES, PT, MLT, IT, CYP, GR



*Figure 19: Added value of the bioeconomy sector.*

*Source: Fraunhofer analysis based on data from JRC*

Geographically, value added in the bioeconomy is rising across the EU, and all macro-regions show increases over time (Figure 20). The strongest growth takes place in the Western Europe, which reaches 49% of the EU value added in the bioeconomy in 2020. Central and Eastern European countries comprise 13% of the value added. Combined with the employment results, this indicates comparably low productivity of the bioeconomy jobs. But over time, value added increases considerably, while employment is falling. This reflects first a catch up of labour productivity and second a structural change of bioeconomy employment towards biomass converting sectors.

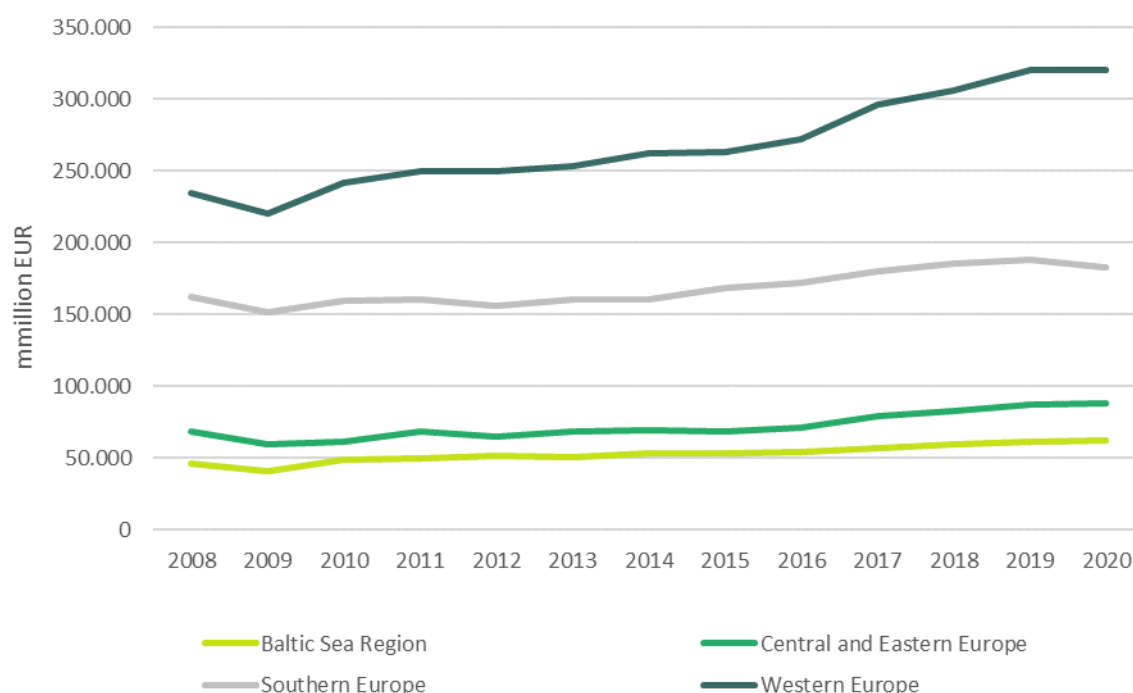


Figure 20: Added value of the bioeconomy sector per macro-region

Source: Fraunhofer analysis based on data from JRC

### 3.4 Overall assessment of indicators

The mapping indicates the bioeconomy plays a vital role in European research landscape and patent activities. Moreover, while bioeconomy is still considered to be in an early maturity stage, but important capacities for biomass processing units have been established. Still questions arise regarding the state-of-the-art, the regional distribution, the focus in terms of feedstocks and processes used as well as products produced.

Regarding the distribution across the EU for all these are important activities and capacities for innovation and production facilities are still very much located in the western, northern and partly southern Europe. Instead, the presence of the mostly more traditional bioeconomy sectors as well as the availability of biomass show a more diverse picture regarding distribution. This divergence of biomass feedstock production and agri-food value chains much located in the Central and Eastern region, but high innovation capacities in other parts of Europe, partly concentrated on few countries, is striking. While activities do not have to be distributed uniformly, still one can conclude that catch-up developments from lagging behind countries as well as the need for coordinated activities across the EU for circular bioeconomy get of high importance to exploit the full potential of the bioeconomy.



## 4 EU Strategies and Policies

In the following part key European strategies will be described, which play a paramount role for the European bioeconomy. The Strategies were selected according to the objectives of the European Bioeconomy Strategy document:

Table 1 Key objectives of the European Bioeconomy Strategy and its interrelations with other strategies

Objectives of the European Bioeconomy Strategy	Other relevant European Strategies
Ensure food and nutrition security	Farm-to-Fork Strategy
Manage natural resources sustainably	EU Biodiversity Strategy
Reduce dependence on non-renewable, unsustainable resources	European Circular Economy Action Plan
Limit and adapt to climate change	European Climate Law
Strengthen European competitiveness and create jobs	European Industrial Strategy

Source: Fraunhofer ISI based on (European Commission, 2022b)

It's important to highlight that the table above does not claim to be complete, but offers a selection of strategies that are directly linked to the objectives of the European Bioeconomy Strategy. The selection was based on the results of the latest European Bioeconomy Progress report. This Progress report also contains a comparison of the main objectives of a larger set of goals, which is included in the Appendix. In a nutshell, a rather large number of strategies share to a certain extent common goals with the EU Bioeconomy Strategy.

### 4.1. Bioeconomy strategies, Action Plans and Related Strategies

#### European Bioeconomy Strategy

The EU Commission adopted its first Bioeconomy strategy “Innovating for Sustainable Growth: A Bioeconomy for Europe” in 2012 (European Commission, Directorate-General for Research and Innovation, 2012). It builds on previous European strategies such as the Biotechnology Programmes (1990s), the Biotechnology Strategy 2002 and the EU Concept for a Knowledge-based Economy (Egenolf & Bringezu, 2019). Among key goals were accelerating the changes, and proposing a comprehensive approach to address the ecological, environmental, energy, food supply and natural resource challenges that Europe and the world are facing today (European Commission, Directorate-General for Research and Innovation, 2012). The strategy indicates, that new technologies can also contribute to the circular use of waste and the extraction of resources, including nutrients, thus promoting resource efficiency and circularity. The revised strategy of 2018 was made up-to-date by the development of a sustainable and circular economy concept (European Commission, 2018) and it is closer to the concept of circular economy than to

the mere re-use of energy, with the aim to strengthen and scale up an already vibrant European bio-based sector.

The EU Bioeconomy Strategy accelerates the deployment of a sustainable European bioeconomy and follows the 5 goals already listed above:

- ensure food and nutrition security
- manage natural resources sustainably
- reduce dependence on non-renewable, unsustainable resources
- limit and adapt to climate change
- strengthen European competitiveness and create jobs.

The strategy contributes not only to the European Green Deal ('The Common Agricultural Policy: 2023-27', n.d.), but also to industrial, circular economy and clean energy innovation strategies. They all highlight the importance of a sustainable, circular bioeconomy. The EU BE Strategy Progress Report assesses the progress of the EU Bioeconomy Strategy from 2018 (European Commission, 2022b) and its action plan, including the identification of gaps for possible future EU bioeconomy actions. The report reflects on the increased importance of the bioeconomy in the new political environment, framed by the European Green Deal. As the current fossil-based economy reached its limits, the transition towards a sustainable and circular use of biological resources has become one of the key goals of the EU. The bioeconomy has the potential to increase policy coherence and to resolve trade-offs, such as already seen on land and biomass demands and can therefore help enabling countries to design transition pathways. Therefore, the bioeconomy plays a central part as it helps to achieve the objectives of the European Green Deal. It also provides solutions for the food insecurity and energy crisis caused by the Russian aggression against Ukraine.

The EU BE Strategy Progress Report refers to the new CAP that includes the bioeconomy explicitly under one of its specific objectives (European Commission, 2022b). EU structural funds remain significant financial contributors to bioeconomy deployment, including the European Maritime, Fisheries and Aquaculture Fund, which has committed EUR 36 million to the blue bioeconomy. (Additionally, the Technical Support Instrument provides additional support to design and implement reforms in EU Member States in the context of EU priorities such as the green and the digital transition.)

- The report also shows that the actions of the Bioeconomy Strategy of 2018 are on a good way in achieving main objectives: Promising developments can be seen in the mobilization of private investments, venture capital and R&I in bio-based industries. Europe shows strengths in the global market for bio-based chemicals and materials.

Among the identified strengths, the report also identifies gaps in the implementation of the action plan. Debatable remains the question how to better manage land and biomass demands, taking into account the environmental and economical requirements for a decarbonized and climate-neutral Europe. The report also claims to elaborate more on sustainable consumption patterns and environmental integrity (European Commission, 2022b).

### **Farm-to Fork Strategy**

The Farm to Fork Strategy ('Farm to Fork Strategy', 2021) is at the centre stage of the European Green Deal ('The European Green Deal', 2021) as the strategy aims to make food systems fair, healthy and more environmentally-friendly (European Commission, 2022b). The Strategy aims to accelerate our transition to a sustainable food system with following aspects:

- have a neutral or positive environmental impact,
- help to mitigate climate change and adapt to its impacts,
- reverse the loss of biodiversity,
- ensure food security, nutrition and public health, making sure that everyone has access to sufficient, safe, nutritious, sustainable food,
- preserve the affordability of food while generating fairer economic returns, fostering the competitiveness of the EU supply sector and promoting fair trade.

Food Systems is a key element of the European Green Deal and its new “Farm to Fork strategy”. Involvement in the Cluster 6 of Horizon Europe initiatives, as well as the European Partnerships, are extremely important tools for achieving the common objectives of creating added value in food systems. The Farm to Fork Strategy (‘Farm to Fork Strategy’, 2021) scales up and promotes sustainable and socially responsible production methods and circular business models. Circular bioeconomy principles offer business opportunities, notably linked to making use of waste (European Commission, 2020c). It also ties in with policies on the recovery of nutrients and secondary raw materials, bioeconomy and renewable energy. Sustainable food systems concept and framework (FAO, 2018b) by FAO says that food systems play a key role in the bioeconomy and therefore require the strategic advice and support, as it is stressed in the Policy Framework “FOOD 2030” and the EU Bioeconomy Strategy (2018).

### **EU Biodiversity Strategy:**

EU biodiversity strategy for 2030 “Bringing nature back to our lives” (‘Biodiversity Strategy for 2030’, n.d.) builds on the need to reverse the overexploitation of biological resources, to combat climate change or to prevent further extinction of our species (European Commission, 2021). Restoring biodiversity therefore is at the core of the European Green deal, the nature restoration law and the EU biodiversity Strategy. Addressing the main drivers of biodiversity and to put in place an efficient governance framework, the EU biodiversity Strategy plays a crucial role in achieving the objectives of the European Green deal and its economic recovery package (European Commission, 2021).

The following four pillars are at the center stage of the strategy:

- Protect Nature - Expand protected areas to 30% of the EU’s land and sea, and put a third of these areas under strict protection
- Restore Nature - Restore Nature and ensure its sustainable management across all sectors and ecosystems
- Enable transformative change - Strengthen the EU biodiversity governance framework, knowledge, research, financing and investments
- EU action to support biodiversity globally - Deploy EU external actions to raise the level of ambition for biodiversity worldwide, reduce the impact of trade and support biodiversity outside Europe

The European Commission highlights that it plans to assess the EU and global biomass supply and demand, understanding better the potential climate and biodiversity risks. Ensuring overall coherence, the strategy emphasizes that it is in line with the Renewable Energy Directive and will develop new sustainability criteria on forest biomass for energy (European Commission, 2021).

### **Circular Economy Action Plan**

The Circular Economy Action Plan of the European Commission sets out a product policy framework in order to increase sustainable production of goods and services (European Commission, 2020a). The action plan provides the strategic orientations of the Commission for other EU institutions to consider and for Member States to integrate in their own national strategies. Under the EU Green Deal, the EU has released its new Circular Economy Action Plan (CEAP). Core themes of the CEAP 2020 are

- the designing of sustainable products,
- empowering consumers and public buyers,
- enhancing circularity in production processes.

In general, circularity is key for the bioeconomy and the CEAP and it shares common goals and principle significantly with the Bioeconomy strategy. More precisely, the Circular Economy Action Plan aims to reduce dependence on nonrenewable unsustainable resources – one of the five goals of the EU Bioeconomy Strategy – by strong focus on waste reduction and consumer empowerment.

Regarding concrete actions the CEAP focuses on seven ‘key product value chains’ where the potential for circularity is high: electronics, batteries and vehicles, packaging, plastics, textiles, construction, and food, water and nutrients. Hence, the CEAP actions only refer to a limited extent explicitly on bioresources. One example for inclusion is the bioeconomy Policy framework for bio-based plastics and biodegradable or compostable plastics.

### **European Industrial Strategy:**

The European Commission presented in 2020 the industrial strategy that aims to support the twin transition to a green and digital economy, make EU industry more competitive globally, and enhance Europe’s open strategic autonomy. In 2021, the Commission updated the EU Industrial Strategy to ensure that its industrial ambition takes full account of the new circumstances following the COVID-19 crisis and helps to drive the transformation to a more sustainable, digital, resilient and globally competitive economy.

In regard, to the EU Bioeconomy Strategy it shares the goal of green growth that secures international competitiveness and jobs, while contributing to environmental goals as well. The Industrial Strategy has three lines of actions that can all contribute to achieve the goal of Bioeconomy Strategy.

- Strengthening of the resilience of the Single Market. The Update focuses on the digital and industrial transition 14 industrial ecosystems. Among these, the Agri-Food sectors has naturally strong relevance for the bioeconomy, while other bio-based converting activities are hardly presented in any of these ecosystem (partly textiles, and renewable energies).
- Supporting Europe’s Open Strategic Autonomy through dealing with dependencies; resulting innovation and trade policy may secure competitiveness of certain bio-based value chains as well
- Supporting the business case for the twin transition. Among others, transition pathways to identify the actions needed to achieve the twin transitions, were co-created jointly with industry and stakeholders. The transition pathway for the chemical industry puts a strong emphasis on bio-based chemicals.

### **European Climate Law**

The European Climate Law establishes the framework for achieving climate neutrality and amending Reregulation aims to reduce gradually greenhouse gas emissions. The scope of the regulation is to establish a framework for the irreversible and gradual reduction of greenhouse gas emissions (‘European Climate Law’, 2021). Overarching goal is to support the ambition of the

European Green Deal to become climate-neutral by 2050. As an intermediate target, the law also intends to reduce net greenhouse gas emissions by at least 55% by 2030 (compared to 1990).

Objectives at the core of the law are the following ('European Climate Law', 2021):

- Set the long-term direction of travel for meeting the 2050 climate neutrality objective through all policies, in a socially fair and cost-efficient manner
- Set a more ambitious EU 2030 target, to set Europe on a responsible path to becoming climate-neutral by 2050
- Create a system for monitoring progress and take further action if needed
- Provide predictability for investors and other economic actors
- Ensure that the transition to climate neutrality is irreversible

Although the prime focus of the law is decarbonization, there are also measures and objectives, which may contribute to overall bioeconomy development in Europe. For instance, the law includes commitments for sector-specific roadmaps in different areas of the economy. Moreover, the law is also in accordance with national energy and climate plans of EU member states, which can incorporate actions in the bioeconomy. For instance, in the realm of the German national and climate plan there are also Carbon Capture and Utilization (CCU) from the bioeconomy sector. Also, the national bioeconomy strategy is aiming at developing sustainably produced bio-based products or using biotechnological production processes, among other aims (European Commission, 2023).

## 4.2 EU Policy and Funding Instruments

In the following, selected key policy instruments are described, which are directly dedicated to the bioeconomy or have a strong link. Policy Instruments include public procurement, tax incentives, subsidies, and grants, which are tools or mechanisms used to support the development and growth of the bioeconomy and to achieve specific policy goals related to the bioeconomy. The description of the policy instruments does not claim to provide a list of all instruments in the bioeconomy, but an overview how these instruments affect the achievement of policy goals in the bioeconomy. Table 2 summarizes those instruments, as well as a few additional ones.

### Horizon Europe

Within Horizon Europe, the main European Framework Programme for Research and Innovation, the Work Programme and the Circular Bioeconomy Joint Undertaking Partnership are directly linked to bioeconomy development in Europe. Please note, that the current level of funding is presented above in 3.1.2.1.

#### Cluster 6 Work Programme:

The Core of Cluster 6 is the need for a transformative change of the EU's economic system and the reduction of environmental degradation, including the halt of biodiversity decline and better management of natural resources. It also considers the geopolitical context and new priorities in research and innovation, strengthening the EU as strategic autonomy in energy and food sector in particular. One of the main objectives is accelerating the transition to sustainable, healthy and inclusive food systems in line with the farm to fork strategy. Through the empowerment of stakeholders, such as farmers, fishers and aquaculture producers production methods will be transformed more efficiently and technological, digital and social innovation will be better used. Research and Innovation will also contribute to fourfold aspects:

- practices at all stages of the food system from production to processing

- services
- the use and valorisation of waste and by-products
- surplus management

### **Circular Bioeconomy Joint Undertaking (CBE JU)**

represent the private sector in a public-private partnership between BIC and the European Commission (BBI JU), and to focus on strengthening the bio-based industries sector in Europe ('From BBI JU to CBE JU', 2022). The aim of the BBI was to support the bio-based industry is an emerging sector that interconnects value chains to maximise the efficient use of renewable bio-based feedstocks into bio-based chemicals, materials, products and energy that can replace fossil-based products. In 2020, the newly launched partnership CBE JU as part of the Horizon Europe Framework Programme was adopted as the official successor of the BBI-JU ('From BBI JU to CBE JU', 2022). The mission of the CBE JU is to implement the Strategic Research and Innovation Agenda (SRIA). The main objectives of the partnership are listed below ('CBE JU: Mission and Objectives', n.d.):

- accelerate the innovation process and development of bio-based innovative solutions
- accelerate market deployment of the existing mature and innovative bio-based solutions
- ensure a high level of environmental performance of bio-based industrial systems

The CBE-JU provides its own Work Programme with various calls based on Annual Work Programme.



### European Circular Bioeconomy Fund (ECBF)

As the first dedicated private venture impact fund, the ECBF is a unique funding instruments in the bioeconomy. At the core of the activities of the fund are substantial investments in technologies, products or business models linked to bio-based innovation. Focus industries include the agri-food sector, forestry, blue economy, industrial biotech, bio-based chemicals and further ones, which play a major role in the bioeconomy ('European Circular Bioeconomy Fund', 2023). In the table below, key investments criteria are displayed.

Table 2: Investment criteria of the ECBF

Geography	EU 27, Horizon Europe associated countries
Stage	Technology Readiness Level (TRL) 6-9, first significant commercial traction
Investment Size	€2.5 - 10 million
ESG Criteria	Commitment with Environmental, Social, and Governance criteria required.

Source: Own table, based on 'Our Investment Focus' (2023)

Among the tasks of the European Circular Bioeconomy Fund (ECBF) are also the provision of equity, quasi-equity, and debt funding to SMEs, midcaps, large caps, and special purpose entities. Jointly developed by the European Investment Bank (EIB) and the European Commission, the fund aims to overcome funding gaps in circular bioeconomy projects and to speed-up the transformation from fossil-based systems towards a circular bio-based economy. Within the portfolio, several companies are received funding from the ECBF, ranging from plastic firms to companies, which are active in the poultry sector ('European Circular Bioeconomy Fund', 2023).

### Common Agricultural Policy Funds (CAP)

As highlighted in the European Bioeconomy Strategy, the agricultural sector plays a pivotal role in the provision of biomass across the EU and is therefore seen as a supreme sector in the bioeconomy. The planned Bioeconomy Strategic Deployment Agenda of the European Commission will build on synergies with other important policy frameworks, such as the CAP or Horizon Europe. Activities of the CAP are therefore highly relevant for the bioeconomy, since bio-based innovation plays also a strong role in the agricultural sector. The CAP is supported by two funds drawn from the long-term budget of the EU, which are presented in the following:

#### European agricultural fund for rural development (EAFRD)

A total allocation of the fund amounts to €95.5 billion and finances the EU's rural development objectives and supports rural enterprises and projects through financial loans, guarantees or equities. The European Agricultural Fund for Rural Development (EAFRD) aims to fulfil the following objectives ('Common agricultural policy funds', 2020):

- Improving the competitiveness of agriculture
- Encouraging sustainable management of natural resources and climate action
- Achieving a balanced territorial development of rural economies and communities

These objectives are carried out by national and regional rural development programmes (RDPs),



which are co-financed by the EAFRD and national budgets of member states ('Common agricultural policy funds', 2020).

### European Agricultural Guarantee Fund (EAGF)

At the centre of the EAGF, is income support for farmers and certain market measures. In the area of income support, the fund differentiates between possible payment schemes, including basic payment, payment for sustainable farming methods and payment for young farmers. The fund support also market measures, such as stabilizing agricultural markets through intervention buying, private storage aid or market disturbance measures ('Common agricultural policy funds', 2020).

Table 3: Overview of EU policy instruments for the Bioeconomy

Name of Policy Instrument	Focus	Focus areas	Type of policy Instrument	Activities/measures related to bioeconomy
<b>Bio-Based Industries Joint Undertaking (CBE JU)<sup>5</sup></b>	Challenges of Europe's bio-based industry. Brings together stakeholders of bio-based industries, boosts innovation and market deployment and paves the way for future investments.	All bio-based sectors	Networking measure, Information, Grants for / (industrial) R&D, Support for public research	<ul style="list-style-type: none"> <li>- R&amp;I support</li> <li>- De-risking investments in innovative, circular bio-based production plants</li> <li>- Addressing the technological, regulatory &amp; market challenges of the bioeconomy</li> <li>- Placing sustainability at the heart of its operations</li> <li>- Strengthening the collaboration of all bioeconomy actors</li> </ul>
<b>Directive on Single-Use Plastics/Packaging Directive/Plastic Bags Directive</b>	EU regulation on single-use plastic products	Chemicals, Pharma & Plastics	Regulation	<ul style="list-style-type: none"> <li>- Directed towards prevention and reduction of the impact of certain plastic products on the environment, in particular the marine environment, and on human health.</li> </ul>
<b>European Agricultural Fund for Rural Development (EAFRD)<sup>6</sup></b>	EAFRD finances the EU's contribution to rural development programmes	Agriculture, Blue Economy, Forestry, Food, Feed and Beverage, Wood	Grants for (industrial) R&D	<ul style="list-style-type: none"> <li>- Improve the competitiveness of agriculture</li> <li>- Encourage sustainable management of natural resources and climate action</li> </ul>
<b>European Agricultural Guarantee Fund (EAGF)<sup>7</sup></b>	Fund will be provided for income support schemes, with the remainder dedicated to supporting agricultural markets.	Agriculture, Blue Economy, Forestry, Food, Feed and Beverage, Wood	Grants for (industrial) R&D	<ul style="list-style-type: none"> <li>- Payment scheme for farmers</li> <li>- Green direct payments (for sustainable farming methods)</li> <li>- Support/payment for young farmers</li> </ul>

<sup>5</sup> [https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/institutions-and-bodies-profiles/circular-bio-based-europe-joint-undertaking-cbe-ju\\_en](https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/institutions-and-bodies-profiles/circular-bio-based-europe-joint-undertaking-cbe-ju_en)

<sup>6</sup> [https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-fund-rural-development-eafdr\\_en](https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-fund-rural-development-eafdr_en)

<sup>7</sup> [https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-guarantee-fund-eagf\\_en](https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-guarantee-fund-eagf_en)

Name of Policy Instrument	Focus	Focus areas	Type of policy Instrument	Activities/measures related to bioeconomy
<b>European Circular Bioeconomy Fund (ECBF)<sup>8</sup></b>	Private venture capital impact fund exclusively dedicated to the (circular-) bioeconomy; ECBF aims to catalyse the transition towards a sustainable future.	All bio-based sectors	Equity support	Funding targeted towards the transition towards a sustainable future.
<b>European Fund for Strategic Investments (EFSI)<sup>9</sup></b>	Bioeconomy is one of the nine sectors that EFSI invests.	Agriculture, Food, Feed and Beverage, Bioenergy and Biofuels, Chemicals, Pharma & Plastics	Grants for (industr.) R&D,	Funding of Small and medium-sized enterprises (with large investment plans of at least €15 million), mid-cap cooperatives and larger private sector enterprises active in the bioeconomy across the European Un
<b>European Innovation Council (EIC)<sup>10</sup></b>	EIC provides various funds to research teams and companies related to bioeconomy. EIC supports game changing innovations throughout the lifecycle from early stage research, to proof of concept, technology transfer, and the financing and scale up of start-ups and SMEs.	Agriculture, Food, Feed and Beverage, Bioenergy and Biofuels, Chemicals, Pharma & Plastics, Blue Economy, Waste and water management	Equity Grants for (industr.) R&D, Support for public research	<ul style="list-style-type: none"> <li>- EIC Pathfinder - Support to research teams to research or develop an emerging breakthrough technology</li> <li>- EIC Transition - Building on promising research results to demonstrate and mature the technology and develop business plans for specific applications</li> <li>- EIC Accelerator - Funding and investments through the EIC Fund for individual start-ups and small companies to develop and scale up game changing innovations</li> </ul>
<b>European Maritime, Fisheries and Aquaculture Fund (EMFAF)<sup>11</sup></b>	Focus on sustainable use of aquatic and maritime resources.	Blue Economy	Equity Grants for (industr.) R&D, Support for public research	<ul style="list-style-type: none"> <li>- R&amp;I support for sustainable blue bioeconomy</li> <li>- transition to sustainable and low-carbon fishing</li> <li>- the protection of marine biodiversity and ecosystems</li> <li>- the supply of quality and healthy seafood to European consumers</li> <li>- the development of a sustainable and competitive aquaculture contributing to food security</li> </ul>
<b>European Regional Development Fund (ERDF)<sup>12</sup></b>	ERDF aims to strengthen economic, social and territorial cohesion in the EU and within its regions	EU Regions	Equity Grants for (industr.) R&D, Support for public research	<ul style="list-style-type: none"> <li>- Innovation and support to SMEs</li> <li>- Greener, low-carbon and resilient economy</li> <li>- Closer to citizens, supporting locally-led development and</li> </ul>

<sup>8</sup> <https://www.cbef.org>

<sup>9</sup> <https://www.eib.org/en/products/mandates-partnerships/efsi/index.htm>

<sup>10</sup> [https://eic.ec.europa.eu/index\\_en](https://eic.ec.europa.eu/index_en)

<sup>11</sup> [https://oceans-and-fisheries.ec.europa.eu/funding/emfaf\\_en](https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en)

<sup>12</sup> [https://ec.europa.eu/regional\\_policy/funding/erdf\\_en](https://ec.europa.eu/regional_policy/funding/erdf_en)

Name of Policy Instrument	Focus	Focus areas	Type of policy Instrument	Activities/measures related to bioeconomy
	towards smarter, greener, more connected Europe.			sustainable urban development across the EU
<b>Green Public Procurement</b> <sup>13</sup>	Green Public Procurement as a voluntary instrument can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market.	Food, Feed and Beverage, Chemicals, Pharma & Plastics, Bioenergy and Biofuels, Wood, Pulp & Paper & Printing, Textiles	Public procurement	
<b>Horizon Europe</b> <sup>14</sup>	Bioeconomy is considered as one of the six clusters of global challenges and Europ. industrial competitiveness in HE. HE facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies while tackling global challenges.	Biodiversity, Agriculture and Forestry, Food and Feed, Circular Economy, Blue Economy, Green Deal, Bio-Based Innovation System, Resilient inclusive healthy and green communities	Support for public research, grants for industrial R&D	<ul style="list-style-type: none"> <li>- R&amp;I support</li> <li>- Addressing the technological, regulatory &amp; market challenges of the bioeconomy</li> <li>- Strengthening the collaboration of all bioeconomy actors</li> </ul>
<b>InvestEU Programme</b>	The fund aims to help use public funding, including funding from the EU budget, to mobilise private investment for a wide range projects carried out in the EU, including bioeconomy.	Agriculture, Forestry, Blue Economy, Biodiversity, Food, Feed and Beverage, Bioenergy and Biofuels	Equity Grants for (industr.) R&D, Support for public research	<ul style="list-style-type: none"> <li>- Sustainable infrastructure</li> <li>- Research, innovation and digitalisation</li> <li>- SMEs</li> </ul>
<b>Knowledge for Policy (K4P) programme</b> <sup>15</sup>	K4P supports policy-making in Bioeconomy by providing scientific evidence. K4P aims to bridge the science-policy gap by bringing together evidence for policy from scientists across Europe, to policy makers across Europe.	Bioeconomy	Networking measure, Information	visualisation tool of bioeconomy in different countries

<sup>13</sup> [https://ec.europa.eu/environment/gpp/index\\_en.htm](https://ec.europa.eu/environment/gpp/index_en.htm)

<sup>14</sup> [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en)

<sup>15</sup> [https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries\\_en#regionalstrategies](https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries_en#regionalstrategies)

Name of Policy Instrument	Focus	Focus areas	Type of policy Instrument	Activities/measures related to bioeconomy
<b>Renewable Energy Directive (RED)</b>	The renewable energy directive is the legal framework for the development of renewable energy across all sectors of the EU economy, and supports cooperation across EU countries.	Bioenergy and Biofuels	Regulation	EU sustainability criteria are extended to cover biomass for heating and cooling and power generation in the revised Directive (EU) 2018/2001. EU countries were required to transpose the new rules by 30 June 2021, and the voluntary schemes have to adjust the certification approaches to meet the new requirements. Additional rules are enshrined in the Implementing Regulation on sustainability certification, foreseen to be adopted in the second half of 2022

Source: Fraunhofer ISI based on various policy instrument descriptions

### 4.3 European coordination groups in the bioeconomy

While the presented policy instruments serve as bioeconomy implementation measures, there exist also a number of different exchange platforms, which advise policy-makers in technical and strategic questions of the bioeconomy as a whole or in some specific sectors. These platforms usually consist of different representatives of the member states and might include also officials from European institutions, such as the European Commission, the European Parliament and others. In the following, two of these platforms will be described in more detail and how they affect the bioeconomy in Europe. The first one is the SCAR Bioeconomy Strategic Working Group, which represents a body under the umbrella of the Standing Committee of Agricultural Research (SCAR) and is therefore a sector specific working group. The second one is the European Bioeconomy Policy Forum (EBPF), which discusses issues for the whole bioeconomy and is therefore not restricted to any specific sectors.

#### SCAR Bioeconomy Strategic Working Group

A platform that is worth noting is the Bioeconomy Strategic Working Group of the SCAR. Established in 1974, the SCAR advises the European Commission and the Member States on the coordination of agricultural research in Europe. It is formed by representatives of 37 countries. The Strategic Working Group can be perceived as an exchange platform that works together with national and European initiatives related to research policy. As a formal coordination mechanism, the Strategic Working Group has been working on political questions in the bioeconomy, for example on the need to develop a revised European Bioeconomy Strategy in 2017, the biomass potential of different European regions or how farmers can profit from the bioeconomy including how they are involved as stakeholders. Other examples include questions how to foster new connections between well-established sectors and how they can sustainably operate in the near future. Moreover, the Group also discusses highly political questions, such as the relationship of bioeconomy policy to other policy areas (e.g., climate, water, food, forestry) ('The Working Group', n.d.). A highlighting example was the observation that the definition of the bioeconomy on the European level does not necessarily reflect the bioeconomy concepts of the individual member states (SCAR, 2017). One of the solutions proposed by the working group is the implementation of a coherent policy framework for the bioeconomy, spanning over all levels of the value chain

and all sectors ('Possible Solutions', n.d.). Further political aspects that are discussed are questions, what the fittest policy framework for the bioeconomy might be, how different interests and different stages towards implementation can be balanced or how to deal with the effects of incoherent policy outcomes ('Barriers', n.d.). The working group consist of representatives of the member states and candidate and associated countries (currently 37 countries in total).

### **European Bioeconomy Policy Forum (EBPF)**

One unique platform for the European bioeconomy is the EBPF, which is taking place twice a year and consists of a High-Level Subgroup and an expert-level subgroup. Each member state can appoint two representatives who are present at both types of meetings. The High-Level group consist mainly of representatives from political institutions, such as secretary generals, deputy minister or head of divisions of bioeconomy relevant ministries. In addition, also officials from the European Parliament, from the Commission (different DGs) or from the Committee of the Regions take part at the forum, but only acting as observers. Recently, also the CBE JU and the European Energy Agency were invited to become member of the group. The platform serves as a formal exchange mechanisms, in which member states have the possibility to discuss essential topics of the bioeconomy.

It is important to note that this platform cannot be seen as a consortium of representatives that sign formal decisions or binding resolutions. In the last years, the platform discussed topics, such as bioeconomy monitoring or planned activities. Scope of the meetings are lessons learned or sharing information regarding updates on the bioeconomy strategies. The EBPF was established as the SCAR Bioeconomy Working Group discussed mainly topics rooted in agriculture, forestry and blue bioeconomy, but not political issues that were perceived as very much important by the members. According to the intervention logic of the forum, main objectives are the following:

- Support networking & interaction at MS level
- Enhance cooperation and best practice exchange
- Shape a concrete agenda of joint actions
- Increase the visibility and potential of the bioeconomy at EU and MS level
- Enable policy feedback and analysis in MS and the EU

## **4.4. Collaborative Structures**

### **4.4.1 Typology of Collaborative Structures**

Over the last decade, the European bioeconomy has witnessed rapid growth supported by increased innovation activities via new emerging partnerships together with the development of additional business opportunities for the stakeholders. This chapter delves into these different emerging collaborative structures, offering an overview of its types and roles, functions, in the evolving landscape of the European bioeconomy.

In the ShapingBio project, collaborative structures refer to different forums, programmes, networks, clusters, hubs, and associations, which are structures or organizations used to facilitate collaboration, coordination, and the exchange of information, resources and best practices between stakeholders and organizations with a shared interest in the development and growth of the bioeconomy.

The field of bioeconomy is vast, encompassing a multitude of sectors from agriculture to energy. Understanding the collaborative structures within this domain is essential to charting its evolution

and assessing the present landscape. The chapter provides insights into the current state of collaborations, the trends driving them, the challenges they face, and their future potential. The selection criteria for mapping collaborative structures in the EU's bioeconomy was done by the following criteria:

- Having direct involvement in the bioeconomy, focusing on initiatives and organizations that contribute to the sustainable and innovative utilization of biological resources.
- Have an impact on the bioeconomy, influence policy, drive innovation, or promote sustainable practices
- Transnationality and EU level involvement.

Once a preliminary list was compiled, the next step involved categorizing these entities based on their main type and function (Table 4). The entities were broadly divided into the following types of collaborative structures: networks, associations, forums, hubs, platforms, programmes and clusters and public-private partnerships.

Table 4: Overview of mapped collaborative structures

Type	Description
Policy and Governance Platforms	Entities that facilitate collaborative policy-making and governance among government, industry, societal groups and academia to drive bioeconomy initiatives.
Networks and Associations	Networks and Associations that connect individuals and entities across the bioeconomy to share knowledge, advocate for common interests, and enhance sector-wide collaboration.
Clusters, Forums, and Hubs	Spaces where businesses, researchers, and stakeholders work together to foster innovation, discuss industry trends, and stimulate economic growth within the bioeconomy.
Research and Innovation Programmes	Structured programmes designed to support scientific research and technological innovation, often through funding, (public-private) partnerships, and knowledge dissemination, to propel the bioeconomy forward.

Public-private partnerships	A (long-term) arrangement between a government and bioeconomy private sector institutions.
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Source: Fraunhofer ISI

To characterize and distinguish the collaborative structures, each identified structure was characterized concerning their type of structure, their functions, and the sector(s) that they represent.

Furthermore, the collaborative structures were assessed by their primary role, i.e. whether they were focused on knowledge dissemination, policy advocacy, research facilitation, or business development (Table 5).

Table 5: Assessment criteria of collaborative structures

Role and Function	Description
Knowledge and Information Exchange	Sharing of specific knowledge and data among stakeholders to drive collective learning and informed decision-making.
Research and Innovation Facilitation	Support and acceleration of research activities and innovation processes, providing a bridge between theory and application.
Business Development and Collaboration	Promotion of commercial opportunities and strategic alliances, enhancing economic growth and competitiveness within the sector.
Policy Advocacy and Governance	Engagement with policy processes to advocate for supportive legislation and regulation, guiding the sector towards sustainable practices and governance.

Source: Fraunhofer ISI

In the following step collaborative structures were evaluated for their involvement in different sectors. The map below encompasses collaborative structures from various sectors within the bioeconomy, ensuring a comprehensive representation of the field. It includes primary production, bio-based chemicals and materials, bio-based energy, food and beverage, education, trade, and environmental conservation. This sectoral diversity reflects the interdisciplinary nature of the bioeconomy and highlights the numerous stakeholders working towards sustainable and innovative utilization of biological resources.

Table 6: Overview of mapped sectors

Sector	Description
Primary Production	Agriculture, forestry, fisheries and aquaculture
Industrial Biotechnology	Industries which produce Textiles, pulp and paper, chemicals, pharma and plastics, wood incl. furniture, others (e.g. construction)
Bio-based Energy	Biogas, biofuels, burning of wood, waste



Food, Feed and Beverages	Industries which produce food, beverages, functional food, food ingredients, alternative proteins, feed and feed ingredients
Environmental protection and waste management	Composting, advanced drinking and waste water treatment, remediation of contaminated sites, exhaust air treatment, environmental monitoring,
Others (Education, Trade and etc.)	(higher) Education, research, training of professionals, qualification of workforce
Public sector	

Source: Fraunhofer ISI research

The map is mostly focused on transnational cooperation and EU level involvement. Collaborative structures that demonstrate cross-border collaboration and engagement at the EU level are therefore highlighted, reflecting the importance of integration of bioeconomy efforts across member states.

Initial data on collaborative structures was sourced from a multitude of sources (JRC reports, EU Knowledge Center Bioeconomy ('The bioeconomy in different countries', 2023), relevant project websites, etc). These offered insights into older, foundational collaborative structures, highlighting their initial aims and their evolutionary journey. Searching in different databases and directories provided a comprehensive list of entities, from associations to clusters. Major bioeconomy summits, workshops, and conferences often publish lists of participants or stakeholders. Such lists were invaluable in understanding active, notable entities in recent years. To facilitate a clear understanding of the collaborative structures, the resulting mapping corporates typologies based on roles and functions, types, and sectors.

#### 4.4.2 Map of Collaborative Structures

The map of collaborative structures in the EU's bioeconomy is a comprehensive visual representation of the diverse collaborative initiatives and organizations involved in the bioeconomy across the EU. This map includes 51 entities, highlighting their type, roles and sectoral focus.

The collaborative structures on the map are represented as distinct entities. Although they might be interconnected, it was beyond the scope of our investigation to depict these inter-connections. The map is designed with a specific color-coding system that aligns with the roles and functions of the collaborative structures, enabling viewers to instantly grasp the magnitude and importance of each entity within the broader bioeconomy. A notable feature of map is its ability to connect collaborative structures across various sectors. For the names of the collaborative structures, please see Annex 2.

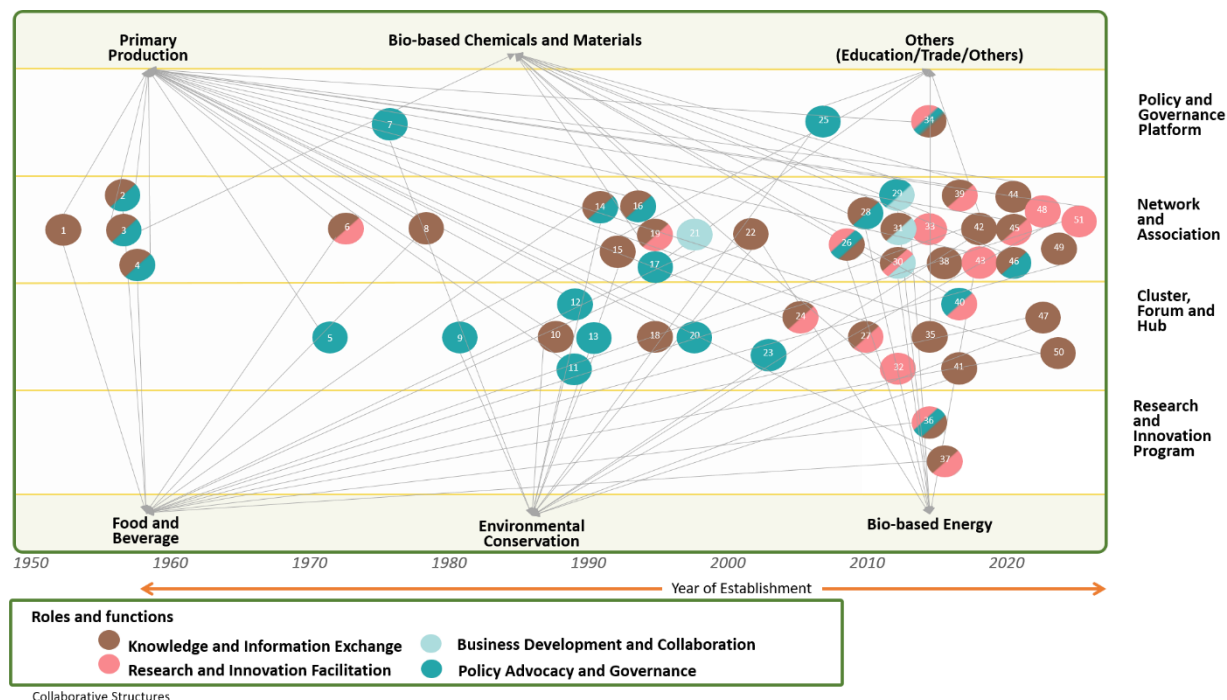


Figure 21: Overview of mapped collaborative structures.

Source: Fraunhofer ISI data collection

The European bioeconomy is an expanding innovation landscape with diverse partnerships and a shared desire for sustainability. Over the past decade, there has been a clear rise in entities emphasizing knowledge and information exchange, as well as championing in research and innovation. This trend needs a collective realization of the value of shared knowledge and collaborative research in achieving the goals of European Green Deal.

Diving deeper into the types of collaborative structures, the group “clusters, forums, and hubs” emerge as the dominant players. Clusters, forums, and hubs have their unique characteristics and roles and their collective contribution to the bioeconomy cannot be underestimated. By fostering collaborations, facilitating discussions, and catalyzing innovations, these structures support the advancement the bioeconomy shape its trajectory and contribute to its resilience.

The early 2010s marked a transformative period in the global bioeconomy landscape, and Europe was no exception. The decade witnessed a rise in collaborative initiatives, reflecting the growing consensus on the importance of interconnected efforts. During the last decade, bio-based chemicals and materials as well as bio-energy have gotten more emphasis. Moreover, while still small, the initial research and innovation programmes and policy-related platforms have been evolving considering the requirements.

An example of this movement was the **European Cluster Collaboration Platform (ECCP)**. Beyond its role as a networking framework, the ECCP represented a dedicated effort to pool resources, expertise, and best practices from across MS. Since its establishment, it has become a nexus for innovation, fostering collaboration between industries, research entities, and policy makers, all with the shared objective of propelling the bioeconomy forward.

Initiatives like the **Bio-based Industries Consortium (BIC)**, established in 2012, is a good example of the evolving nature of public-private partnerships in this era. Recognizing the vast

potential and the myriad challenges of the bioeconomy, BIC strived to bring more than 400 industrial stakeholders, researchers, and policy makers under a singular umbrella, streamlining efforts towards realizing a sustainable and integrated European bioeconomy.

In parallel, the **European Bioeconomy Network (EuBioNet)** emerged as another vital hub, acting as a repository and channel for knowledge related to about 150 EU-funded bioeconomy projects in 2018. By bridging the gaps between diverse stakeholders, EuBioNet facilitated a smoother flow of information, supporting the harmonization of research, policy decisions, and on-ground implementations with overarching bioeconomy goals. The initiative is promoted by the Transition2Bio project.

**BIOEAST** is one of the key collaborative networks in the Central and Eastern European landscape, created in 2016. It serves as one of the key instruments in bringing together bioeconomy actors from various Central and Eastern European countries and facilitates a number of different support schemes and mechanisms to aid strategic research and innovation in the bioeconomy domain of the region.

The **Nordic Bioeconomy Panel, set up by the Nordic Council of Ministers in 2016**, is tasked with developing a strategy for the region, including identifying practical steps to foster sustainable bioeconomies. Similarly, the West Nordic Bioeconomy Panel, it, aims to devise a robust strategy for the region, comprising Iceland, Greenland, and the Faroe Islands. This initiative focuses on preserving and enhancing the region's bioeconomy and effectively communicating the formulated strategy.

The **DanubeBioValNet** was launched in 2017, it is a cross-regional collaboration, engaging partners from 10 distinct regions along the Danube. Its core focus is on developing and enhancing three bio-based value chains: phytopharma, eco-construction, and bio-based packaging (notably bioplastics). Additionally, the project places a significant emphasis on advancing the hemp industry, leveraging regional strengths to foster innovation and sustainable development in these key sectors.

The **AlpLinkBioEco** and **Bioeco-RDI-ADRION** initiatives foster linkages between diverse sectors and industries and support a circular, bio-based economy in respective regions.

The **BioInnovation Growth Mega-Cluster (BIG-Cluster)** is a cross-border 'Smart Specialisation Initiative' set up in 2013 focused on revolutionizing Europe's industrial mega-cluster. Spanning the Flanders region of Belgium, the Netherlands, and the German state of North Rhine-Westphalia, BIG-Cluster's objective is to elevate this area into a leader in bio-based innovation. By promoting partnerships and advancing bio-based value chains, BIG-Cluster contributes to innovation and sustainable development within the sector.

The **3BI Intercluster, established in 2015**, consists of the German BioEconomy Cluster that focuses on wood, BioVale from the UK that focuses on biowastes, the French IAR that focuses on the valorisation of renewable resources from agriculture, forest and algae, and the Dutch Biobased Delta that focuses on novel biological resources for its chemical industry. It emphasizes the extraction of valuable chemicals from natural resources, including plants and microbes, ensuring that its innovations are consistent with environmental cycles.

The **SUBMARINER Network for Blue Growth's** primary focus is on the blue bioeconomy, with its endeavours being proof for the broadening horizons of the bioeconomy discourse. The activities of the institutionalised network created in 2014 (with a full time central secretariat) and a budget of more than EUR 220 million gathered since then underscore the potential of marine resources, from algae to aquatic plants, highlighting their utility in sectors ranging from energy and pharmaceuticals to food and textiles.

The **Vanguard Initiative**, a player in industrial innovation since 2014, emphasizes the role of establishing European value chains with the bioeconomy as a foundational element. This initiative

embodies a strategic contribution to raise the bioeconomy as an aspect of Europe's growth and development plans. By fostering collaborations and focusing on sustainable, bio-based industries among more than 30 European regions, the Vanguard Initiative aims to integrate the bioeconomy deeper into Europe's economy, ensuring its role in the region's future economic landscape and environmental sustainability.

These collaborative hubs represent only a small part of a larger effort. In the background, a variety of research projects and new industrial developments are underway, all aiming to create a bioeconomy that is robust, environmentally friendly, and economically beneficial. This highlights the extensive work being done to advance the bioeconomy, focusing on environmental health and economic growth.

#### 4.5 Concluding Remarks

This chapter presented the EU policy landscape for the Bioeconomy as well as a mapping of transnational collaborative structures in the EU bioeconomy. While a full assessment of the EU bioeconomy policy concerning potential gaps, coherence or impact is beyond the scope of this Deliverable, some observations can be deduced.

It is crucial that the EU continues to work in collaboration with other global regions and respects with its policies all the relevant sustainability dimensions, i.e. the well-being of the EU citizens and preservation of ecosystems as the demand for bio-based materials is increasing. The EU bioeconomy policy has evolved via dedicated strategies, but its strong cross-sectional character becomes obvious as the formulated goals are also partly subject to and influenced by a significant set of other strategies. While the common goals may indicate potential synergies, an assessment of the coherence and coordination is not trivial. In trend, the bioeconomy and its parts do not play a very explicit role in overarching strategies like New Circular Economy Plan, the Industrial Strategy or the European Climate Law. Hence, still potential for a better integration of the bioeconomy field in the overall policy mix likely exists.

The mapping of policy instruments reveals that significant policy support for "traditional fields" of the bioeconomy like the primary sector, but also for converting industries have evolved. These are mainly R&D&I policies, but also to some extent dedicated equity financing instruments by the EIB have been developed. However, similar as for almost all countries, relatively few demand-side policy instruments exist that significantly foster or steer the transition to the bioeconomy.

Relevant policies are mostly dealing with cross-cutting issues such as regulation of use and disposal of plastic, energy use or sustainable public procurement, and hardly provide direct impulses for bio-based products and processes.

The chapter also highlights a crucial role of collaboration for the EU bioeconomy. We have identified and mapped a selection of key collaborative structures in the EU. Even though no information could be collected how well these entities fulfil their functions, and which impact they have, their role in the overall development of the bioeconomy scene is non-questionable, despite the challenges, such as addressing regulatory differences between different countries and sectors, transparency in the decision making and operational structure and an effective stakeholder engagement. This mapping provides an initial overview of collaborative structures in the EU, and serves as an input for later workpackages of the ShapingBio project to further study how they address these different challenges, and which good practice can be derived and replicated across different collaborative structures with the EU. Among others, it shows a rise in collaborative initiatives in the last decade, reflecting the growing consensus on the importance of interconnected efforts. During the last decade, bio-based chemicals and materials as well as bio-

energy have gotten more emphasis. Moreover, while still small, the initial research and innovation programmes and policy-related platforms have been evolving considering the requirements.

## 5 Conclusions

This report provides an inventory of the bioeconomy initiatives, instruments and key innovation indicators in the EU, based on the identified information needs in the ShapingBio project and additionally provides some key insights from the international level. Its findings are in line with a number of other studies of the bioeconomy sector in the EU, illustrating that despite numerous policies and support mechanisms, there is an increased need for additional bioeconomy governance mechanisms to support bioeconomy stakeholders, but especially businesses at all the levels and geographical locations to transform bio-based innovations into sustainable economically profitable businesses. EU was one of the leading bioeconomy global regions a decade ago, but meanwhile the global competitors have been catching up in terms of policies and bioeconomy governance, illustrating the urgency in the EU to speed up the processes of creating a more favourable innovation ecosystem for the bioeconomy sector. Furthermore, the EU is obliged to consider in its policy planning international actions and initiatives conducted by other states and countries as well as International organizations. For instance, as new technologies based on renewable raw materials and biological principles are becoming available, bioeconomic transformation could help to achieve the United Nations' SDGs. However, bioeconomic transformation is not necessarily sustainable. To design effective enabling and regulatory governance frameworks for bio-based transformation, policy makers have to identify potentially game-changing future technologies and assess associated sustainability gains and risks. The differences in strategies and policies between the EU and other global countries are significant. Consequence of that is a continuous adaptation of the EU framing in all levels (structural, legislative, financing and social).

On the EU level, the EU Green Deal from 2019 already targets a transition towards a low-carbon sustainable model of growth, food and energy security, biodiversity and natural resource management, where it is envisaged that the bioeconomy will play a key role. Furthermore, on a MS basis several approaches have been adopted characterized by the sources of growth and transitional stage of the bioeconomy and different indicators in this report reveal that the bioeconomy has maintained its relative importance within the total EU27 economy. At the EU level, agriculture and the food industry have played a key role in driving a transition in the primary and industrial bioeconomy sectors due to their significant labour productivity-enhancing impact. Nevertheless, numerous open questions remain ranging from how to create a level playing field for the different uses of primary resources to which value chains are most profitable and sustainable of the bioeconomy sector. Also, despite numerous efforts on the governance level, there is still an ongoing debate on how to best balance different interests towards the transitions of bioeconomy and what the fittest governance model of bioeconomy in the EU should eventually look like.



## 6 Appendices

### Annex 1

#### Assessment of relation of strategies and goals of the Bioeconomy Strategy

In the following, the assessment of the EU Progress Report (European Commission, 2022b) concerning the relation of various strategies and goals of the Bioeconomy Strategy.

Table 7: Assessment of EU Green Deal in relation to the Bioeconomy Sustainability Objectives

**Table 1.** Assessment of EU Green Deal initiatives in relation to bioeconomy sustainability objectives. The table shows how the European Green Deal initiatives focus on ('dark green') or support ('medium green') the sustainability objectives of the EU Bioeconomy Strategy or if specific attention is required to maintain overall coherence ('pale green').

		Ensuring Food and Nutrition Security	Managing Natural Resources Sustainably	Reducing dependence on non-renewable unsustainable resources, whether sourced domestically or from abroad	Mitigating and adapting to climate change	Strengthening European competitiveness and creating jobs
Circular Economy	[1]					
Industry Strategy	[2]					
Biodiversity Strategy	[3]					
Farm to Fork Strategy	[4]					
Renovation Wave	[5]					
European Climate Law	[6]					
Chemicals Strategy for Sustainability	[7]					
Adaptation Strategy	[8]					
Sustainable Financing	[9]					
Zero Pollution Action Plan	[10]					
LULUCF	[11]					
Renewable Energy	[12]					
Forest Strategy	[13]					
Sustainable Carbon Cycles	[14]					

[1] COM(2020)98. A new Circular Economy Action Plan. For a cleaner and more competitive Europe. [2] COM(2020)102. A New Industrial Strategy for Europe. And COM(2021)350 final. Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery. [3] COM(2020)380. EU Biodiversity Strategy for 2030. Bringing nature back into our lives. Targets include protection 30 % of the land and sea area, strictly protection of 10 % of land and sea area; reverse decline of pollinators; 50 % reduction in the number of Red List species threatened by invasive alien species; significantly reduce by-catch of species; three billion new trees are planted in the EU; aligned to targets of the farm to fork strategy. [4] COM(2020)381. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. Targets by 2030 include 50 % reduction in the use and risk of chemical pesticides and a 50 % reduction in the use of the more hazardous pesticides, hazardous chemicals, nutrient losses, and sales of antimicrobials in farming; 25 % of agricultural area under organic farming. [5] COM(2020)662. A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. See also COM(2021)802 proposal for a directive on the energy performance of buildings (recast). [6] EU(2021)1119. 'European Climate Law'. Targets include by 2030 reduction of GHG emissions by 55 %; achieving climate neutrality by 2050. See also Carbon Border Adjustment Mechanism COM(2021)564 final. [7] COM(2020)667. Chemicals Strategy for Sustainability - Towards a Toxic-Free Environment. [8] COM(2021)82. Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change. [9] COM(2021)390. Strategy for Financing the Transition to a Sustainable Economy and EU(2020) 852. Taxonomy Regulation. [10] COM(2021)400. Pathway to a Healthy Planet for All - EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'. Targets by 2030 include reduce number of premature deaths by air pollution by 55 % and share of people chronically disturbed by transport noise by 30 %; sign, waste generation, residual municipal waste and plastic litter at sea (by 50 %), microplastics released into the environment by 30 %; nutrient losses and chemical pesticides' use by 50 %; EU ecosystems where air pollution threatens biodiversity by 25 %. [11] COM(2021)554. Proposal for amendment of the LULUCF regulation. Target of -310 Mt CO<sub>2</sub>eq/yr net greenhouse gas removals in the EU-27 LULUCF sector, with individual targets by Member State. [12] COM(2021)557. Amendment of EU(2018) 2001. On the promotion of the use of energy from renewable sources. Targets of amendment include increased to 40 % share renewable energy, increased sustainability criteria incl. cascading principle. [13] COM(2021)572. New EU Forest Strategy for 2030. [14] COM(2021)800. Communication on Sustainable Carbon Cycles; including a target of 20 % of the carbon used in the chemical and plastic products from sustainable non-fossil sources by 2030 and announcing an action on Integrated Land Use Assessments.

Table 7 illustrates the relationship between the European Green Deal initiatives and the five objectives of the Bioeconomy Strategy. Each initiative focusses on at least one goal the Bioeconomy Strategy (dark green) and supports others (light green). If the link with the objective of the Bioeconomy Strategy is only implicit, it is marked with pale green.

Table 8 illustrates different challenges that need to be addressed: (a) increased pressure on land for mitigation and adaptation, nature protection (e.g., biodiversity) and supply of biomass, (b) increased demands for materials and bioenergy, and (c) a mismatch between the existing and required work force.



Table 8: Assessment of the EU Green Deal in relation to the Bioeconomy Sustainability Objectives

SWD Table 3. Assessment of EU Green Deal initiatives in relation to bioeconomy sustainability objectives. The table shows how the European Green Deal initiatives focus on ('dark green') or support ('medium green') the sustainability objectives of the EU Bioeconomy Strategy or if specific attention is required to maintain overall coherence ('pale green').

		Ensuring Food and Nutrition Security	Managing Natural Resources Sustainably	Reducing dependence on non-renewable unsustainable resources, whether sourced domestically or from abroad	Mitigating and adapting to climate change	Strengthening European competitiveness and creating jobs
<b>Circular Economy</b>	[1]		Reduced waste reduces pressures on the environment; precautions for chemicals of concern taken	Very strong focus on waste reduction and consumer empowerment	No explicit mention, but reduced consumption 'throughflow' implicitly contributes to climate mitigation.	Some support to the economic transformation; international engagement.
<b>Industry Strategy</b>	[2]		Link to circular economy action plan. Circular electronics initiative.	Action plan on critical raw materials; sustainable textile and chemical strategies	Comprehensive strategies to contribute to the climate targets: clean steel and other energy-intensive industries; renovation wave; offshore renewable energy. Carbon Border Adjustment. Just Transition Platform to support regions facing challenges.	Focus on green growth, including international and trade policies and working conditions
<b>European Climate Law</b>	[6]				Target on GHG emissions reductions by 2030 and climate neutrality by 2050.	
<b>Chemicals Strategy for Sustainability</b>	[7]		increasing sustainability of chemicals through a 'safe and sustainable by design' initiative	Protect consumers against harmful substances, minimise substances of concern thus facilitating circularity; advanced materials; address dependencies for strategic value chains.	low carbon production processes	access to risk finance; improve chemicals governance
<b>Adaptation Strategy</b>	[8]	Not mentioned - adaptation measures might impact FNS	Nature based solutions and systemic approaches are promoted but without concrete measures; specific measures on water use.	No consumption based action that reduces dependency.	Actions focus strongly on 'preparedness; and in the improvement of knowledge, monitoring & modelling of impact, capacity building and cooperation. No target or concrete measure.	Capacity building and financial instruments are included

<b>Biodiversity Strategy</b>	[3]	Exclusion of land and sea area from production and/or extensification can lead to conflicts with food production.	Targets on land and sea protection, pollution by pesticides and nutrients, high ambitions in protecting natural and managed ecosystems, including agriculture, forestry, marine and freshwater ecosystems.	Focus on international cooperation and consumption-oriented actions, such as the legislation on 'placing of products associated with deforestation or forest degradation', global/international engagement including equity aspects.	Synergies between biodiversity and climate mitigation and adaptation likely but trade-offs possible e.g. through additional land demand.	Sustainable finance, biodiversity business models. Exclusion of land and sea area from production and/or extensification can lead to conflicts with businesses.
<b>Farm to Fork Strategy</b>	[4]	Broad range of actions to increase nutrition, including through the CAP, fighting non-communicable diseases, though no quantitative targets and mainly 'soft' actions planned. Focus on food safety with target to reduce antimicrobials.	Strong focus on sustainable production with targets on pesticides, nutrients, and organic farming practices; additional actions planned to improved sustainability monitoring.	Resource efficiency addressed focusing on reduction of retail and consumer food waste; overall consumption sustainability addressed by informative policies.	Planned activity on carbon farming will contribute to climate mitigation; organic farming can increase resilience, but no target on agricultural GHG emissions or adaptation.	Individual actions to protect primary producers and protect them with respect to other food chain actors and to fight food fraud
<b>Renovation Wave</b>	[5]	Additional demand for bio-based materials.	Additional demand for bio-based materials.	Integration of resource efficiency and sustainability principles, considering the life-cycle and resilience of buildings.	Contribution to climate target in the building sector.	Focus on affordability; fight against energy poverty; various financial instruments used to leverage uptake.

<b>Sustainable Financing</b>	[9]	Food and nutrition security, indirect effect on land demand not addressed.	Sustainable taxonomy includes as environmental objective production including the sustainable use and protection of water and marine resources, the protection and restoration of biodiversity and ecosystems through sustainable management, and pollution prevention and control.	Sustainable taxonomy includes as environmental objective the transition to a circular economy; methodology based on life cycle approach; global cooperation considered; indirect effects not addressed.	Sustainable Taxonomy strong focus on climate mitigation and adaptation; improving access to green financing; climate neutral digital technologies.	Sustainable financing including social investment as important enabler of green and just growth.
<b>Zero Pollution Action Plan</b>	[10]		Improve quality of air, water, soil, as well as fighting loss of terrestrial and marine biodiversity loss.	Reducing waste; promoting zero pollution consumption pattern; reducing health inequalities.	Contributing to ecosystem health increasing resilience	
<b>LULUCF</b>	[11]		Reporting requirements for biodiversity-rich land to promote synergies between carbon management and management of natural resources		Climate mitigation target for the LULUCF sector.	

<b>Renewable Energy</b>	[12]	Potential land demand of renewable energy; limits set for energy from food and feed crops as well as fuels potentially associated with indirect land use change.	Additional land demand; strong safeguards introduced, such as the cascading principle and no-go areas, as well as lowering the threshold for installations	Reduction of dependence on fossil energy; possible new material demand for renewable energy technologies.	Share of renewables in the EU energy mix to 40% by 2030; enhanced sustainability criteria of bioenergy incl. GHG saving thresholds.	Creates jobs in the renewable energy sector; improves competitiveness; additional requirements could increase burden on businesses; challenges in fossil sectors.
<b>Forest Strategy</b>	[13]		Protecting, restoring and enlarging forests to strengthen their multi-functionality and resilience	Optimise wood use within sustainable limits in line with the cascading principle and the circular economy approach.	Climate benefit through LCA; carbon farming initiative.	Promote non-wood forest-based employment opportunities and capacity building for sustainable forest management. Additional requirements could increase burden on businesses.
<b>Sustainable Carbon Cycles</b>	[14]	Additional land needs through extensification and material demand; integrated bioeconomy land use assessments to avoid adverse effects.	Co-benefits of carbon farming practices.	Substitution of fossil based products.	Contribution to climate mitigation through ecosystem carbon sequestration and storage of carbon in products.	New markets and industry investments

## Annex 2

### Names of collaborativ structure on Figure 20

1. European Association of Sugar Manufacturers (CEFS)	27. SUBMARINER Network for Blue Growth
2. European Farmers and European Agri-Cooperatives (COPA-COGECA)	28. European renewable ethanol association (ePURE)
3. European Vegetable Oil and Protein Meal Industry (FEDIOL)	29. Bio-based Industries Consortium (BIC)
4. European Starch Industry Association (Starch Europe)	30. European bio-based knowledge network (new name: MNEXT)
5. Conference of Peripheral Maritime Regions (CPMR)	31. Vanguard
6. Standing Committee on Agricultural Research (SCAR)	32. Bio Innovation Growth mega Cluster (BIG-Cluster)
7. Mediterranean Action Plan (MAP)	33. Brokering Bio-Based Innovation (3Bi)
8. European Vegetable Protein Association (EUVEPRO)	34. Central and Eastern European initiative for knowledge-based agriculture, aquaculture and forestry in the bioeconomy (BIOEAST)
9. Islands Commission (CPMR)	35. European Cluster Collaboration Platform (ECCP)
10. European Forum for Nature Conservation and Pastoralism (EFNCP)	36. Nordic bioeconomy
11. Atlantic Arc Commission (CPMR)	37. EIT Food
12. North Sea Commission (CMPR)	38. The European Bioeconomy Alliance (EUBA)
13. Intermediterranean Commission (CPMR)	39. ForestValue
14. Alliance for Beverage Cartons and the Environment (ACE)	40. Trilateral Strategy
15. The Union of the Baltic Cities (UBC)	41. One Planet Coalition
16. Confederation of European Paper Industries (CEPI)	42. European Bioeconomy Network (EuBioNet)
17. Baltic Sea States Sub-Regional Cooperation (BSSSC)	43. Forest Policy Research Network
18. International Partnerships Facility of the European Forest Institute (EFI)	44. Med Sea Alliance
19. European Bioplastics (EUBP)	45. European Network on Climate-Smart Forestry
20. Baltic Sea Commission (CPMR)	46. Biomass-derived Chemicals in Europe (BioChemEurope)
21. European Association for Bioindustries (EuropaBio)	47. EU Food Loss and Waste Prevention Hub
22. European Regions Research and Innovation Network (ERRIN)	48. European Biodiversity Partnership (Biodiversa+)
23. Balkan & Black Sea Commission (CPMR)	49. European Network for a Plant-Based Diet (PlantEurope)
24. Forest-based Sector Technology Platform (FTP)	50. EU's Common Agricultural Policy (CAP) Network
25. Union for the Mediterranean (UfM)	51. Sustainable Blue Economy Partnership (SBEP)
26. European Biogas Association (EBA)	



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## THE PARTNERS

