



STRATEGIC RESEARCH AND INNOVATION AGENDA SUMMARY



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BIOEAST INITIATIVE

The Central and Eastern European (CEE) Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bioeconomy – BIOEAST – offers a common political commitment and shared strategic research and innovation framework for working towards sustainable bioeconomies in the CEE countries.



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The development of sustainable European bioeconomies is a big challenge for the upcoming decade and is a common challenge for the whole of Europe. A sustainable bioeconomy depends on future advancements and requires substantial investments in education, research and innovation. Consequently, this challenge should be seriously considered by the Central and Eastern European (CEE) countries, which have significant biomass potential but are lagging behind in terms of education, research and innovation.

BIOEAST Initiative, the CEE countries' Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bioeconomy, was established in 2016 to provide a political platform for the CEE countries to strengthen research and innovation cooperation and to enhance participation in the shaping of the European Research Area's (ERA) policy and framework programme. The BIOEAST Initiative was founded by the Ministers of Agriculture of Czechia, Hungary, Poland, Slovakia, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Romania and Slovenia. The BIOEAST Initiative represents the common political commitment and shared strategic research and innovation framework for working towards sustainable and circular bioeconomies in the CEE countries.



BIOEAST.EU

1 THE BIOEAST INITIATIVE AND ITS VISION

The mission of the BIOEAST Initiative is to unlock the sustainable bioeconomy potential and address the generally low level of bioeconomy maturity in the CEE countries. Pursuing this goal requires a strengthening of the knowledge base, research and innovation excellence, strategic planning, governance, cross-sectoral cooperation, and integration with leading European and international initiatives in the broad field of bioeconomy. The vision of BIOEAST Initiative envisages the region in 2030 as

'a European Research Area addressing knowledge and cooperation based circular bioeconomies by combining conventional (bioeconomy) sectors with innovative bio-based technologies'.

The five main challenges that hinder the region's performance and require action are, as follows:

1. Research and innovation deadlock characterised by poor R&I infrastructure and weak links between industry and academia, which results in limited practical application of research results.
2. Stalemate in the value chains, which hinders the more effective use of biomass in traditional bio-based value chains as well as the utilisation of opportunities in innovative ones.
3. Difficulties in the integration of the multidisciplinary bioeconomy concept with conventional sector-oriented public policies.
4. Societal indifference towards bioeconomy.
5. Generally low access to finance and low level of public-private endeavour in pooling resources for R&I.

The BIOEAST Initiative and the macro-region will contribute towards achieving the EU's long-term goals through addressing the five above-mentioned challenges. The activities of the Initiative will help to:

- promote the development of a knowledge-based circular and sustainable bioeconomy in the CEE countries;
- make European industries greener, more circular and more sustainable;
- reduce the dependence on non-renewable resources, and improve energy supply security;
- make Europe climate neutral, and mitigate and adapt to climate change;
- preserve and restore ecosystems and biodiversity, and reduce pollution.
- enhance the competitiveness of the macro-region and create new jobs;
- boost the bioeconomy education curricula and skills development;
- develop fair, healthy and environmentally friendly food systems, and improve food and nutrition security;

The BIOEAST Foresight Exercise pointed out that circular bioeconomy has enormous potential for the growth of the BIOEAST region. The development of bioeconomy can help in phasing out fossil fuels and fossil-based products and in reducing greenhouse gas emissions. Furthermore, bioeconomy provides an opportunity to develop new value chains and business models, which could attract private and public investments. These could include, for example, increasing the resilience of forests to climate change or supporting the use of new breeding technologies that provide tools for the faster development of crops that are suitable for a wide range of agroclimatic conditions and have better resistance to pests and plant diseases, thereby responding to climate change more effectively. Additionally, education and digitalisation are enablers of a more rapid transition to a circular and sustainable bioeconomy.

In 2021, following the insights from the foresight report, the ministries of the countries participating











in the BIOEAST Initiative agreed on a common position paper, which emphasises that establishing sustainable and circular bioeconomies in the CEE countries is of paramount importance in achieving circularity and climate neutrality by 2050. The position paper calls for urgent steps to be taken at governmental level to invest in three key programmes – specific national bioeconomy-related education, bioeconomy research and innovation and bioeconomy development programmes.

2 STATE-OF-THE ART

2.1. BIOECONOMY IN THE BIOEAST MACRO-REGION

The BIOEAST macro-region includes 11 CEE countries (Bulgaria, Czechia, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia) with more than 102 million inhabitants (25% of the total population of the EU in 2020) and covers 1 135 290 km² of area (25% of the EU area). The bioeconomy of the BIOEAST macro-region employed around 7.06 million people and generated EUR 94.4 billion of value added in 2019 (Table 1). The turnover was estimated at EUR 335.2 billion in 2019.

Table 1. Employment and value added generated in the biomass producing and manufacturing sectors in the BIOEAST macro-region in 2019

Number of employed in biomass producing and converting sectors, thousand	BIOEAST macro-region's share of employment in biomass producing and converting sectors, % of EU	Value added of biomass producing and converting sectors, billion EUR	BIOEAST macro-region's share of value added of biomass producing and converting sectors, % of EU	
7 060	41	94.4	14	
Value added per person employed in biomass producing and converting sectors, thousand EUR				
BIOEAST macro-region		EU		
13		38		
Sector (NACE rev.2)	Employment, thousand jobs	Employment, %	Value added, billion EUR	Value added, %
 Agriculture	4 491.9	63.6	33.5	35.5
 Forestry	271.1	3.8	6.0	6.4
 Fishing and aquaculture	21.1	0.3	0.6	0.7
 Food, beverages and other agro-manufacturing	1 186.8	16.8	29.3	31.1
 Bio-based textiles	243.0	3.4	3.0	3.1
 Wood products and furniture	586.0	8.3	10.8	11.4
 Paper	158.3	2.2	5.9	6.2
 Bio-based chemicals and pharmaceuticals, plastics and rubber	93.9	1.3	4.5	4.7
 Liquid biofuels	6.1	0.1	0.3	0.3
 Bioelectricity	5.0	0.1	0.5	0.6

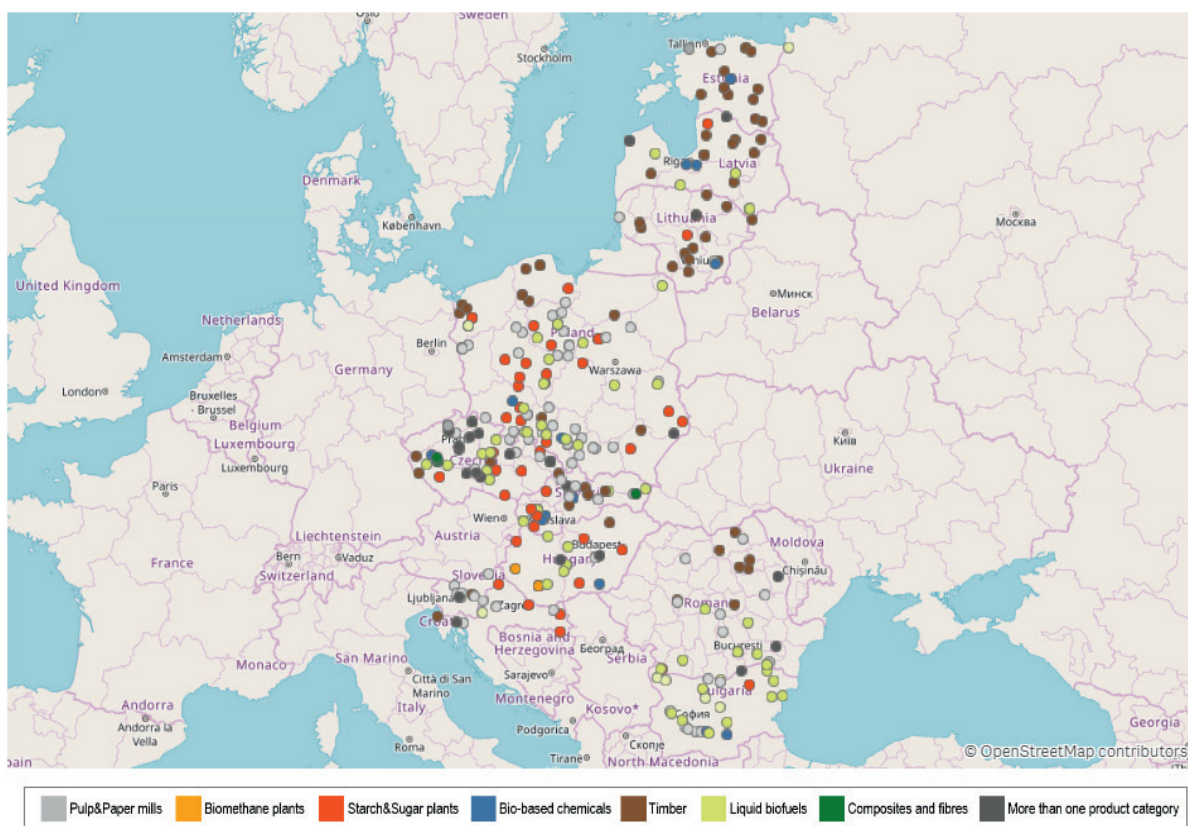
Source: Joint Research Centre, 2022; European Commission, 2022.

The bioeconomy in the BIOEAST macro-region is concentrated in traditional sectors, as well as in low technology and low-productivity industries. The average labour productivity in the bioeconomy of the BIOEAST macro-region is about three times lower than the EU average. During the 2008-2019 period, the total value added of the bioeconomy increased at an average annual growth rate of 2.3%, whereas total employment in the bioeconomy decreased at an average rate of 2.5% per year. However, the decrease in employment has not taken place across all sectors of the bioeconomy. In the 2008-2019 period, employment increased in sectors such as bio-based electricity, liquid biofuels, bio-based chemicals, pharmaceuticals, plastics and rubber, and paper. In these sectors, the average growth rates of value added were the highest among the bioeconomy sectors. These sectors also had the highest labour productivity among the bioeconomy sectors in the BIOEAST macro-region, indicating where the focus of the bioeconomy development could be.

Agriculture is the biggest producer of domestic biomass with 79% of the total in the BIOEAST macro-region, followed by forestry with 21% of the dry matter content. The proportion of the fishery sector is less than 1%. Approximately 59% of the available biomass is used for food and feed, with biomass for energy and biomaterials accounting for 24% and 17%, respectively. Waste and by-streams could be a source for development of novel value chains in the BIOEAST macro-region. The current bioeconomy players are having the advantage of already producing bio-based products but still must undergo the transition to the circular and sustainable bioeconomy. This includes not only developing new value chains for waste and by-product streams but also using clean energy and improving resource efficiency in the production system.

The Joint Research Centre report data on 314 facilities using biomass for the manufacturing of products in the BIOEAST macro-region (i.e. 13% of the EU total) (Figure 1). Most of the bio-based facilities (97%) of the BIOEAST macro-region are commercial, while the number of demo- or experimental plants is small.

Figure 1. Map of the distribution of the bio-based industry in the BIOEAST macro-region

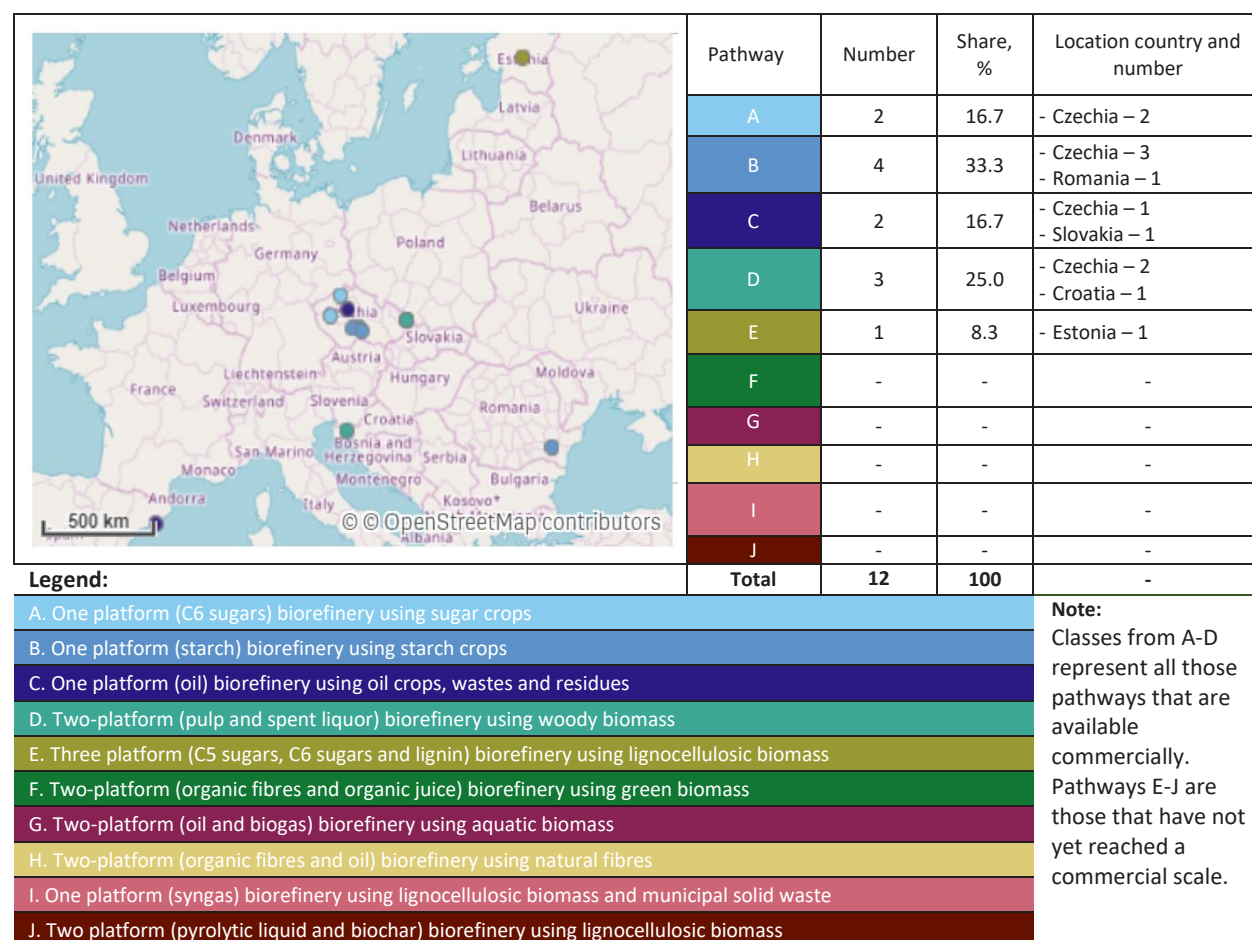


Source: DataM, 2022a.

Agricultural and forestry feedstocks are the most widely used general feedstock classes in the BIO-EAST macro-region. Agricultural and forestry feedstocks processing facilities are concentrated in Poland and Czechia. Waste-based facilities are mainly concentrated in Bulgaria and Czechia. The relatively small number of grasses and short-rotation coppice-based facilities represented in the database can be found in Lithuania and Slovakia. Three main categories of products produced by bio-based facilities in the BIOEAST macro-region are liquid biofuels, pulp and paper, and timber. Biomethane production accounted for the smallest number of bio-based processing facilities, but in many cases combined heat and power producing biogas plants have been and are being upgraded for biomethane production.

The Joint Research Centre report noted 12 existing chemical and material driven biorefineries in the BIOEAST macro-region (Figure 2), which account for only 4% of the EU chemical and material driven biorefineries (298 biorefineries in the EU). In addition to the relatively small number of biorefineries, the number of pathways they exploit is also limited. In the BIOEAST macro-region, the most frequent pathway is represented by pathway B 'One platform (starch) biorefinery using starch crops'. The second most frequent pathway is represented by D 'Two-platform (pulp and spent liquor) biorefineries using woody biomass'. Other frequent pathways in the BIOEAST macro-region are pathways A and C.

Figure 2. Distributions of chemical and material biorefineries by pathways in the BIOEAST macro-region



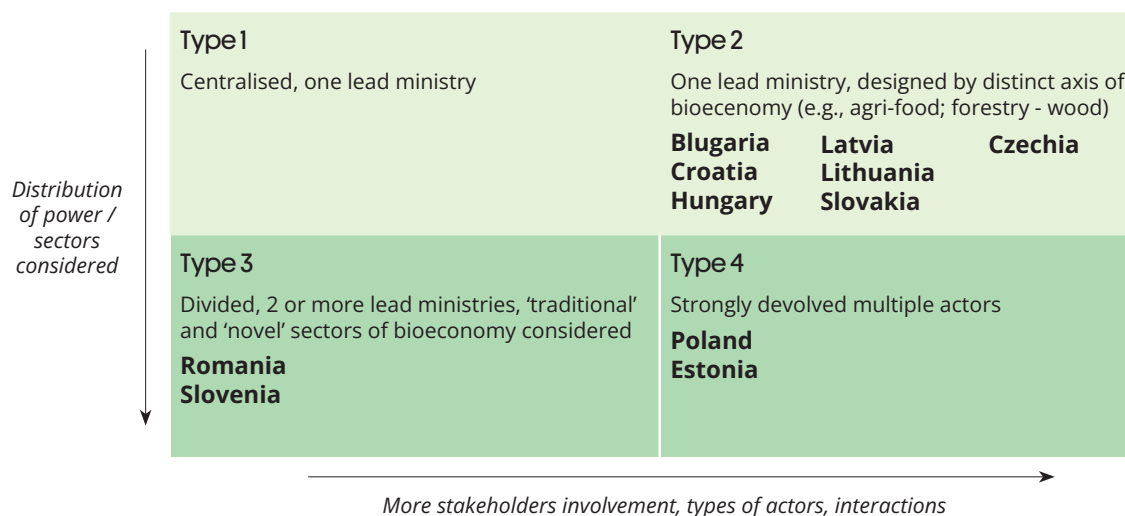
Source: DataM, 2022c.

2.2. REGULATORY FRAMEWORK AND INSTITUTIONS

The EU bioeconomy strategy ‘A Sustainable Bioeconomy for Europe: Strengthening the Connection between the Economy, Society and the Environment’ was updated in 2018. Ten EU Member States have adopted a national bioeconomy strategy, of which only one is a BIOEAST country – Latvia (in 2017). There are currently seven EU Member States that are in the process of developing their respective strategies, of which four are BIOEAST countries. Croatia, Czechia and Slovakia have started the process of developing a national strategy. Other BIOEAST Member States (Bulgaria, Romania, Slovenia) opted to integrate the bioeconomy in sector-specific or cross-cutting policies, e.g., Bulgaria is currently developing a strategy for ‘Strengthening the Role of the Agricultural Sector in the Bioeconomy’ and the ‘National Strategy for Transition to a Circular Economy’. Poland is in the process of developing its bioeconomy related actions as part of a roadmap for circular economy. The Estonian Government adopted a national policy framework document on the bioeconomy in 2022, followed by the circular bioeconomy roadmap, which is planned to be adopted by the government in 2023. In Hungary and Lithuania, work towards a dedicated bioeconomy strategy, launched before the 2018 European Bioeconomy Strategy, has not yet been concluded (European Commission, 2022; Directorate-General for Research and Innovation, 2022). Figure 3 illustrates the different governance models and institutional mixes in the BIOEAST countries.

Figure 3. Types of governance/ministerial arrangements in BIOEAST Member States

Source: BIOEAST. 2021. Bioeconomy institutional profiles – comparative analysis, benchmarking and policy recommendations



(Deliverable 1.4.).

The individual member states have been encouraged to further consult the conclusions of the Bioeconomy Policy Support Facility’s Mutual Learning Exercise run by the European Commission, which has determined 10 recommendations for the region, along with the reflection of the BIOEAST ministries and of the BIOEAST Advisory Board about the BIOEAST foresight experts’ recommendations. Results of institutional analysis suggest that crucial factors for boosting the bio-based value chains lie elsewhere than merely a clear institutional structure, or the existence or non-existence of national bioeconomy strategies.

It is tangible that in most of the countries the bioeconomy is developing at individual project level. However, in some cases, though the deployment is supported at policy level, the lack of political commitment and priority setting clearly affects the orientation of the market and public actors in a negative way. Without clear political commitment at governmental level, the individual actors or programmes cannot perform and develop efficiently. Moreover, the quality of relations between actors and their willingness for cross-sectoral cooperation significantly affects the deployment of a sustainable circular bioeconomy.

Accordingly, one of the key challenges at governmental level is the integration of research and technology-oriented policy making. The development of knowledge-based policy requires the direct involvement of a sector-related research and innovation perspective in the highest ministerial structure.

Closing the gap with the leading bioeconomy regions in Europe will require a coordinated effort of key actors and elements representing their respective bioeconomy institutional environment. Apart from the challenges outlined above, changing the status of the macro-region from the provider of biomass to a producer of value-added industrial bio-based products requires a qualitative change in macro-regional collaboration, through adopting the bioeconomy cluster approach in which regional feedstock supply, existing industrial infrastructure, know-how and public support are combined.

2.3. BIOECONOMY RESEARCH AND DEVELOPMENT

The BIOEAST macro-region is a lagging region in the EU in terms of R&D investment; however, that gap is decreasing and approaching the EU average. The area where the BIOEAST macro-region is lagging the most is business investment in R&D and innovation. The countries with the largest amount of R&D expenditure in the business sector also have a higher share of this expenditure in total R&D expenditure on average. In Poland, Czechia, Hungary and Slovenia, which have the largest business expenditure on R&D (BERD) amounts, this accounts for more than 60% of total R&D expenditure. Of the countries with smaller amounts, the share of BERD exceeds 60% in Bulgaria alone. The smallest amount of BERD and its share in the general expenditure on research and development (GERD) is observed in Latvia and Lithuania, where it is significantly lower than the EU average. The Baltic countries and Croatia have the least research-intensive business sectors, as the public sector – higher education and government – tends to spend more on R&D than the private sector.

In 2019, 436 200 full-time equivalent workers were employed as R&D personnel and researchers in the BIOEAST macro-region (15% of the EU total), of whom 51% worked in the business enterprise sector. Their number has been growing in recent years, rising from 273 500 in 2010. The R&D personnel and researchers in the business sector are mainly working in other sectors and manufacturing. The R&D personnel and researchers employed in the agriculture, forestry and fishing sector account for a negligible share of total employment in the business sector.

In the BIOEAST macro-region, a net EU contribution under Horizon 2020 amounted to EUR 2 958.5 million, which accounted for 5% of the total net EU contribution in the EU in 2014-2020. H2020 funds intensity per capita was more than three times lower in the BIOEAST macro-region than in the EU (EUR 29 vs EUR 110 per capita) during the same period. The highest net EU contribution per capita was in Estonia and Slovenia, while the other BIOEAST countries were far behind (Bulgaria, Poland and Romania were the lowest ranked). In comparison with the EU, a relatively higher share of the net EU contribution to bioeconomy-related programmes was allocated in the BIOEAST macro-region with the highest difference in the SC2 programme 'Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy' (7% vs. 5%). Among the BIOEAST countries, the highest SC2 share was reported in Slovakia (21%), followed by Romania (13%), Latvia (9%), Hungary (8%), Estonia and Croatia (9% each), while the lowest shares were recorded in Czechia (4%), Poland (5%) and Slovenia (6%).

In general, the intensity of patenting activity was much lower in the BIOEAST macro-region than across the whole EU with differences from 8 to 27 times in applications per million inhabitants. Compared with the EU, the BIOEAST countries were relatively more focused on research and technology development in the fields of pharmaceuticals, basic materials chemistry and food chemistry. The total share of bioeconomy-related citable publications in the BIOEAST macro-region was at a similar level as that in the EU (around 27-28 %). The publications of the BIOEAST macro-region showed a relative specialisation in agriculture and biological sciences research areas, while the EU as a whole was focused more on biochemistry, genetic and molecular biology. The citable scientific publication intensity per 1 million inhabitants was higher in the EU than in the BIOEAST macro-region in all areas, except for veterinary science.

3 ADDRESSING THE CHALLENGES

In order to strengthen the European Research Area (ERA) by creating synergies between the actors of different countries, envisaging research and innovation needs and connecting relevant organisations in the BIOEAST macro-region to the EU bioeconomy networks, the BIOEAST Initiative has established seven Thematic Working Groups (TWG) that operate as a lasting macro-regional network of thematic experts from ministries, academia and industry:

- Agroecology and Sustainable Yields;
- Food Systems;
- Forestry Value Chains;
- Bioenergy and New Value-added Materials;
- Advanced Biochemicals and Biomaterials;
- Freshwater Based Bioeconomy;
- Bioeconomy Education.

Each of the TWGs is responsible for one of the BIOEAST Core Themes, which are further structured into several Strategic Thematic Areas. In each of these Strategic Thematic Areas, challenges, main research topics, and expected outcome and impact have been elaborated on. In addition, overarching challenges and research topics have been identified that are common to several Core Themes.

4 CORE THEMES

OVERARCHING ISSUES

The BIOEAST thematic working groups have outlined the main challenges, strategic thematic areas to address these challenges and expected outcomes. However, this process clearly outlined some overarching challenges that need to be addressed, and which would have an impact on the development of more than one thematic area. In particular, these include: (i) development of dedicated inter-ministerial bodies, specialised platforms, networks and stakeholder clusters to foster the development of the bioeconomy; (ii) adoption of the bioeconomy cluster approach, where regional feedstock supply, existing industrial infrastructure, know-how and public support are combined; (iii) databases on the supply, quality and characteristics of primary and secondary biomass, and marketplaces for biomass suppliers and processors, regional R&D infrastructure and know-how.

AGROECOLOGY AND SUSTAINABLE YIELDS



CHALLENGES

There are common challenges in the agriculture of the BIOEAST macro-region that need to be addressed through targeted regional cooperation. These include **climatic and ecological** challenges as well as a lack of **long-term, strategic systems thinking and planning** in agricultural policy and among stakeholders, which is essential for evidence-based decision-making. **The transition pathways from fossil and chemical input-based intensive farming to agroecological practices** should be considered as opportunities rather than hindrances. There is a need to overcome a **strong top-down and monodisciplinary approach** among stakeholders and to promote innovation and collaboration. It is crucial to enhance **the participation of social stakeholder groups in decision-making processes**.

STRATEGIC THEMATIC AREAS

In agroecology, the SRIA is structured around six thematic areas. Regarding **soil management**, it is important to promote the transition to environmentally sound, **low-emission, soil-friendly agricultural technologies**. Research is needed on improving the carbon sequestration capacity of soils in order to establish a scientific basis for soil advisory systems. In addition to establishment of Living Lab and Light Houses networks for the **transition to chemical pesticides-free agriculture**, measuring ecosystem services as well as improving the monitoring and forecasting systems of pests and invasive species by integrating plant protection with state-of-the-art digital tools is needed. In the area of **genetic resources and agricultural diversification**, research on climate-adaptive plant and animal breeding techniques needs to be strengthened. In addition to the creation of resilient new varieties, upscaling of the organic seed sector is a priority. **Innovation, smart agriculture, digitalisation and knowledge sharing** should focus on developing new ICT solutions and sharing them with agricultural producers to support their decision making in the conditions of environmental and climate changes. Another priority is the development of incentive and motivation systems to facilitate the participation of agricultural operators in agricultural data initiatives, along with tracking the latest innovations for knowledge sharing. In order to achieve **sustainable animal husbandry and animal welfare** there is a need to reduce the use of antimicrobials and facilitate technological shifts to ensure better animal welfare conditions. Furthermore, the production of quality agricultural products (e.g. feed) while reducing environmental pressure needs to be strengthened. In order to support **rural development**, research on developing the sustainability and viability of small-scale and family farms, along with other rural businesses, is needed. This considers the development of data-based decision support systems as well as circular and sustainable business models to strengthen local food supply chains and shorten the input and output chains of raw materials.

OUTCOMES AND IMPACT

The implementation of the outlined research, development and innovation activities contributes to **improved evidence-based policy making** that would serve the development of a circular sustainable bioeconomy in the macro-region. Most importantly, it would encourage a **widespread multidisciplinary and multi-actor approach in agricultural research**, which would position the macro-region better in terms of European bioeconomy research. It would also help the region become more **well-prepared and able to adapt to climate extremes and more resilient to agro-socio-economic disruptions**.



FOOD SYSTEMS

CHALLENGES

Food systems are mutually interdependent and complementary systems of agriculture, processing, waste management and interacting with the external environment, and they include, among others, energy, distribution, healthcare, culture and traditions. Structural changes in the food systems are either exogenous or endogenous. The challenge is to create sustainable food systems that ensure food security at the local, national, regional and global levels by considering the current and future environmental and climate constraints and the contemporary challenges of economic and social development.

STRATEGIC THEMATIC AREAS

In order to tackle the challenges for **sustainable food production**, the knowledge and technology transfer skills of primary producers need to be upgraded; new agricultural models should be developed to replace models based on the increased use of fossil-based fertilisers, and chemical plant protection; sustainable transport, storage and packaging solutions are needed; and organic and less intensive farming models in agriculture need to be empowered. In order to achieve a better **balance in the distribution of power and information in the food systems**, there is a need for a systemic approach to boost innovation and investment in short food supply chains; integration of renewable energy sources; trust-building for collective actions; digitalisation of agri-food value chains; data on food fraud; and strengthening the bargaining position of farmers in supply chains. **Research, innovation, technology and investments for future sustainable food systems** need to address the data needs for modelling food system dynamics; mapping the available databases for further decision making processes; involving players from the food supply chain in research; modern educational framework on sustainable food use; increasing the efficiency of the biological methods of control; stimulating the growth of plant defence system and biodiversity in agriculture; and research on the social, poverty and demographic problems. **The shift to sustainable food consumption and healthy diets** calls for increased consumer awareness of food quality, sustainable choices and increased public awareness on the ways to reduce food waste. New industries for healthy life and food need to be promoted. More knowledge is needed about new paths for the development of aquatic and urban food systems as a source of alternative proteins.

OUTCOMES AND IMPACT

The implementation of the research agenda will increase the level of innovation as a result of investments in human and physical capital; technological development leading to the resilience of primary production and supply chains; the creation of modern research infrastructures; and the involvement of society in processes of transformation towards sustainable food systems. Achieving such a state will be conducive to the development of methods for the systemic management of the food chain with the full involvement of all stakeholders, including producers, processors, distributors and consumers.

FORESTRY VALUE CHAINS



CHALLENGES

Forest resources are under **pressure due to climate change** and **changing societal demands**, which result in changes of the goods and services demanded from forest ecosystems. The severe impacts of climate change will lead to a need to strengthen the capacity of forests **to adapt to new conditions**, as well as to adapt respective forest-based value chains. Maintaining and strengthening forest biodiversity, productivity, regeneration capacity, vitality and the potential of forests to fulfil ecological, economic and social functions requires the further development of **new techniques and technologies, value chains and business models**. The competitiveness of the value chains based on forestry and forest biomass and keeping rural areas vital requires **innovation in the provision of goods and services**, smart logistics and **digital transformation** in forest management and wood processing, the building of modern **biorefineries** and employing the principles of **the cascading use** of forest products in a circular economy.

STRATEGIC THEMATIC AREAS

These challenges call for the development of modern forest inventory systems, silvicultural systems, breeding, modelling and risk assessment that support decision making processes for the **management of forest resources in changing conditions**. Tools for planning of forest operations, smart logistics and digitisation are seen as important in optimising infrastructure and work operations and in facilitating **sustainable production**. The adaptation to changing conditions leads to the structural changes of forests, e.g. tree species diversification in favour of broadleaves, and requires the adaptation of wood processing technologies by **strengthening traditional and developing high-tech wood processing industries**, increasing the processing of logs of broadleaf species and widening their industrial use. Considering the need for the substitution of non-renewable materials, especially in packaging, innovations in **pulp and paper technologies** lead to the development of special papers and functional fibres for other industries. The efficient use of biomass needs to build on **the recycling and cascading system of wood and wood products**, where wood use is cascaded according to its properties, preferring the highest added value products that are recycled at the end of their life with the closing life cycle of wood use in residual **biomass for bioenergy**, including the use of residuals after oxidation. Socio-economic research on employment should contribute to the development and optimised provision of the **forest ecosystem services** required by society and mitigating the trends of rural abandonment. Through research in the optimisation of forest structures, infrastructure, development and implementation of commercial payment and incentive schemes for provision of forest ecosystem services, the forest sector should further support **regional development** and economic growth in rural areas. It is important to ensure that the results of research, development and innovation reach forestry students in vocational schools and universities as well as stakeholders and the general public through innovation in **forestry education and communication**.

OUTCOMES AND IMPACT

The implementation of the outlined research, development and innovation activities contributes to better knowledge of the structural changes in forests in changing environmental and societal conditions. It also adds to the improved capacity of forests to adapt to ongoing climate change through purposefully differentiated forest management systems, repurposed management decisions and material flows, while building new and innovative value chains and business models for products and services based on improved knowledge and innovative technology.



BIOENERGY AND NEW VALUE-ADDED MATERIALS

CHALLENGES

While acknowledging that the energy sector is a source of large portion of GHG emissions due to fossil fuel combustion, embedding bioenergy in a circular and sustainable bioeconomy has some unleashed potential to contribute to a carbon-neutral future. However, there are several challenges in integrating bioenergy with the pathway to an economically viable and carbon-neutral EU by 2050. The lack of awareness about the value of bioenergy side stream products such as bioheat, CO₂, ash and digestate, as well as the uncertainty, seasonality and quality of raw materials and bioenergy supply undermines its faster market uptake and utilisation of the potential of side products. The commercialisation and transfer of new technologies into the market remains a difficult endeavour. Even with the technology developed and upscaled, the challenge of ensuring compatibility with the current infrastructure remains.

STRATEGIC THEMATIC AREAS

The existing linear business models fail to maximise the substitution effect from fossil based to bioenergy production; therefore, soon, the current business models itself will not be enough to secure the market presence of bioenergy. The valorisation of all bioenergy by-products and the development of whole value chains are necessary for the transition to circular bioenergy business models with energy and grid balancing potential. Hence, actions are needed that foresee pathways for the **integration of bioenergy in the circular bioeconomy**. The mobilisation of secondary biomass is needed to stabilise biomass supply and secure the sustainability of bioenergy production. Furthermore, the implementation of post-harvesting techniques would contribute to reducing GHG emissions in line with **improving biomass quality for bio-based industry**. The choice of bioenergy technology is closely connected with biomass potential and availability. A decrease in fossil fuel dependency and achieving carbon neutrality lies in the untapped potential of the cascading use of biomass sources for bioenergy. The countries in the BIOEAST macro-region have the potential for better utilisation of **bioenergy sources to decarbonise their national economies** by integrating bioenergy in the energy and emission intensive sectors. The maximisation of biomass usage can be accomplished through the establishment of local, small-scale collection hubs. Harmonising demand for biomass for bioenergy with other bioeconomy sectors and securing compatibility with the current infrastructure of the fossil-based system is crucial to the generation of added value. The integration of biomethane and hydrogen production is leading to ensuring the energy independence and stability of the EU energy supply. New and emerging energy storage and uptake technologies support **bioeconomy defossilisation** in addition to accomplishing policy framework.

OUTCOMES AND IMPACT

The implementation of the outlined actions is expected to lead to the reduction of GHG emissions through the integration of value added from bioenergy side streams and grid balancing. Stabilisation of biomass supply and the cascading use of biomass in the BIOEAST macro-region are among the most cherished goals. Through the establishment of collection hubs, the goal is to maximise the use of underutilised secondary biomass sources and reduce competition between food, feed and fuel from primary crops. In order to ensure a climate-neutral bioeconomy, the transcription of mature technologies is achieved with a strong focus on innovation through research and technology development. A systemic structure and interdisciplinarity with empowered cooperation between key actors will be created.

ADVANCED BIOCHEMICAL AND BIOMATERIALS



CHALLENGES

Despite the **large amount of biomass** produced in the BIOEAST macro-region, bio-based value chains are not yet well developed, particularly within the blue bioeconomy. **The lack of detailed information** on the characteristics and volume of primary and secondary biomass streams, **insufficient biorefinery capacities** and **technological challenges** all hinder the transition of the chemical industry from fossil-based resources to renewable ones. The various steps involved in the conversion of biomass must be further developed, and new processes invented, so currently untapped biomass fractions and various side streams can be efficiently turned into a range of **high-value products**.

STRATEGIC THEMATIC AREAS

To tackle the above challenges, the chemical and biotechnological conversion of terrestrial and aquatic biomass into functional additives, platform chemicals, materials and innovative products for demanding applications needs to be developed. Through the **Assessment of sustainable feedstocks for the chemical industry**, the collection of up-to-date information on biomass supplies that has the potential to be valorised in the chemical industry is supported in order to boost the formation of bioeconomy clusters, resulting in more mature value chains. Particular attention is given to the role of the **blue economy in the production of bio-based chemicals and materials**. Besides pursuing technological developments related to the **chemical and enzymatic transformation of biomass**, small- and intermediate-scale biorefineries need to be established to enable the scaling up of new processes. In terms of products, high-value applications are primarily targeted. Innovative strategies are needed to produce **bioactive and functional compounds**, including their extraction, purification and conversion, for use in the medical, pharmaceutical and cosmetic industries, among others. The efficient utilisation of biomass requires converting waste and side streams from existing value chains into various **bio-based materials and platform chemicals**: monomers, polymers, binders and adhesives. Novel applications areas, however, often create new types of challenges. The unique properties of bio-based compounds should be exploited to provide **innovative high-value bio-based products for demanding applications**, e.g., in biomedicine and battery technologies.

OUTCOMES AND IMPACT

The implementation of proper monitoring systems for biomass flows contributes to the development of bio-based value chains, increasing biorefinery capacities and introducing new strategies for the conversion of waste and side streams into innovative, high-value products. This helps to better integrate first stage biomass producers into the bioeconomy as suppliers of renewable resources for the chemical industry. The improved profitability of biotechnological production processes could attract further investment, leading to job creation and providing businesses with new opportunities.



FRESHWATER BASED BIOECONOMY

CHALLENGES

Fresh water is important for the countries in the BIOEAST macro-region. However, the majority of water bodies in the region have worse than good status, as overall economic development has increased the range and amount of various pollutants. The BIOEAST macro-region needs to urgently mitigate the impact of climate change on ecosystems, improve water management and develop applicable new solutions for the reduction of water use, proper management of rainwater and development of drought management plans. **However, the implementation of any agenda related to these issues is scattered, though several ministries and entities are engaged.** An additional challenge, which is closely associated with freshwater management mentioned above, is the cleaning of water bodies and maintaining their clean and safe conditions.

STRATEGIC THEMATIC AREAS

The fragmentation in governance of freshwater-related issues needs to be urgently tackled to map and connect all relevant policy makers and align the existing structures. This has the potential to enhance the eco-innovation system and to facilitate the discussion among stakeholders about a common approach, long-term vision and subsequent research, development and innovation needs. There is a need to provide evidence-based solutions for policy makers to advocate for the restoration of water bodies and to monitor and improve water quality both in rivers and water areas. New technologies are required to approach invasive species in freshwater, separate and utilise micro plastics, and exploit sediment. The development of a digital twin in silico river models can speed up finding the optimal solutions for inland waters and rivers, and it can also support promising freshwater aquaculture and multi criteria impact analysis on both water and soil ecosystems. There is a demand to develop new business models and value chains based on freshwater to attract private investors. Additionally, due to the fact that most freshwater sources (lakes or rivers) are shared by multiple countries, cooperation and harmonisation of the related regulations and approaches is mandatory.

OUTCOMES

The implementation of the above-mentioned research topics will enhance the achievement of an environmentally-sustainable freshwater based bioeconomy and will have a positive impact on biodiversity. **The deployment of the Danube river basin lighthouse under the European Missions to Restore our Ocean and Waters by 2030 can provide solutions for fresh water that can be put in place to increase the quality of inland water bodies and rivers. BIOEAST Thematic Working Group Fresh Water Based Bioeconomy has the potential to act as a macro regional science policy network where different interests can be discussed, and national initiatives can be networked so it can act as a horizontal enabler of the EU Mission.**

BIOECONOMY EDUCATION



CHALLENGES

The BIOEAST Foresight Report identified the lack of bioeconomy-related education and skills in the BIOEAST macro-region as the key risk of failure in accomplishing the goals of the European Green Deal and connected EU strategies. New transdisciplinary curricula should be developed, and existing ones should be adjusted to ensure knowledge-based transformation towards a biobased economy. Additionally, there is an obvious need for developing vocational training. BIOEAST Initiative has initiated the new BIOEAST Uni Net network of bioeconomy universities, which will act as a collaborative platform for developing bioeconomy education in the macro-region.

STRATEGIC THEMATIC AREAS TO TACKLE CHALLENGES

There is a need for a systemic mapping of the bioeconomy education landscape in the BIOEAST macro-region, as well as the identification and evaluation of the existing programmes and structures, and their synergies in relation to the socioeconomic dynamics for the respective countries. Additionally, it is highly beneficial to align the regional educational priorities with other regions, particularly in the western part of Europe. The following topics are of key importance: education on sustainable entrepreneurship, programmes for investors and managing authorities. To enhance bioeconomy education, it is crucial to: a) develop guidelines for policy makers on how to implement bioeconomy education frames; b) support awareness raising and knowledge exchange activities; c) enhance training for sustainable entrepreneurship including sustainable financing, by providing some case examples of place-based and context-specific circular comprehensive bio-based business models. The BIOEAST Uni Net can strengthen the **regional education arena** by: i) identification of education needs both in regard to the entrepreneurship potential and the gaps in the labour market; ii) **forecast** analyses and data; iii) **support** the educational organisations in implementing the bioeconomy programmes including lifelong learning, coaching, peer review learning and providing practical supervision services; iv) **develop tutorials** to support green public procurement and other instruments and for sustainable transition towards a (circular) bioeconomy.

OUTCOMES

The implementation of the above-mentioned actions will support the public and industrial sector to align along the sustainability priorities with the framework for bioeconomy education. The universities and in general the education system will have the capacity to significantly contribute to the understanding of bioeconomy. The BIOEAST Initiative will be able to advance in the above-mentioned challenges, continue acting and articulating the demands, and specify needs, while connecting policy makers and universities from the BIOEAST macro-region with counterparts from all over Europe.

5 THE EU'S ADDED VALUE

The successful implementation of the BIOEAST SRIA will provide the following benefits to the EU:

- consolidated human capital in research and innovation,
- a stronger research and innovation system,
- targeted and more competitive research,
- cooperation, exchange, networks,
- new high-quality knowledge,
- achieving EU policy priorities implemented,
- a reduced gap between the BIOEAST macro-region and the EU innovation leaders,
- unlocked sustainable circular bioeconomy potential.

The BIOEAST Foresight Exercise pointed out that the circular bioeconomy is an enormous opportunity for the growth of the BIOEAST region and forecasted that the adoption of a fully sustainable and circular bioeconomy model would have the following impacts.

IMPACT ON ECONOMIC DEVELOPMENT AND GROWTH LEVELS

Adoption of bioeconomy principles will have a direct impact on economic development and growth in both the mid- and long-terms. Besides this, the potential investments will be observed, and an alignment to common European practices and an attempt at the synchronisation of the BIOEAST countries are required. Direct impact will be achieved through various means of funding, exploration of specific investments, participation in related projects, consortia etc. Indirect economic impact will be achieved by adopting practices such as biomass valorisation, enabling new value chains, circularity, sustainable production lines and cooperation between various sectors. Undertaking research and innovation activities in all the thematic areas mentioned above will also lead to synergy effects in the economies of the CEE countries.

IMPACT ON COMPETITIVENESS

Given that sustainability is a key element in all bioeconomy practices, it will make the regional economy more competitive by supporting not only bioeconomy-related pathways but also actions in totally different businesses and domains. Another parameter that influences competitiveness is the regional character of the bioeconomy. New technologies and innovations are expected to have an applicability to the whole CEE macro-region and explore the regional advantages, such as natural resources, market size, alternative value chains, complementarity, competitiveness, and homogeneity of attitudes and perceptions, as well as development and growth. Bioeconomy development will help the CEE region reach the standards of Northern and Western Europe in terms of competitiveness, market exploration, growth and attracting investments. Collaboration is essential for the implementation of circular and bioeconomy business models. Instead of competing in the traditional sense, radical collaboration must be encouraged. The goal of increasing know-how and knowledge of modern cooperation is a challenge. Cooperatives can be helpful in moving towards various circular bioeconomy objectives, especially when the cooperatives themselves work closely together (policy measures aimed at cooperatives have the potential to reach a large proportion of agricultural producers, for example). But this is not a given – overcoming trust and transparency issues are problematic without appropriate know-how.

SOCIETAL AND ENVIRONMENTAL IMPACT

The creation of technologically advanced jobs is one of the main societal impacts that a bioeconomy provides. Additionally, and in the same context, the bioeconomy will also enable investments and development in lateral or related domains, which will result in indirect job creation. An additional aspect is an increase in awareness and understanding. Adoption of the circular bioeconomy requires a high level of awareness. Vocational education or case-by-case training are processes that add to this perspective.

Citizens are changing their behaviour patterns regarding purchasing and consumption, becoming more

engaged in the co-creation of circular bioeconomy solutions and better connected. The sense of community and interdependency is getting stronger.

After summarising the expected outcomes and impacts of Strategic Thematic Areas, we can forecast that implementing the BIOEAST SRIA would contribute to achieving:

- the BIOEAST Initiative long-term goals,
- as well as the BIOEAST's Vision 2030 – to develop knowledge and cooperation-based circular bioeconomies, which helps to enhance their inclusive growth and create new value-added jobs, especially in rural areas, maintaining or even strengthening environmental sustainability.

A bioeconomy approach is based on sustainability, so the environmental impact of full implementation is positive. The circular character of the process further enhances this positive impact.

COHERENCE WITH EU POLICIES AND ACTIVITIES

The Strategic Thematic Areas of the BIOEAST SRIA are quite broad; therefore, multiple partnerships and missions may be in the focus of each of the Thematic Working Groups. According to the Strategic Thematic Areas identified, the Thematic Working Groups have established links to the following European Partnerships and HE Missions:

- Circular Bio-based Europe Joint Undertaking (the CBE JU Partnership),
- European Biodiversity Partnership: Biodiversa+,
- European Partnership Accelerating Farming Systems Transition: agroecology living labs and research infrastructures,
- European Partnership for Animal Health and Welfare,
- European Partnership for Agriculture of Data,
- European Partnership for Rescuing Biodiversity to Safeguard Life on Earth,
- European Partnership for A Climate Neutral, Sustainable and Productive Blue Economy,
- European Partnership for Safe and Sustainable Food Systems for People, Planet & Climate,
- European Partnership for Water Security for the Planet (Water4All),
- European Partnership for Clean Energy Transition,
- Clean Hydrogen Partnership: European Partnership on Clean Hydrogen,
- Partnership: Towards zero emission road transport (2Zero),
- the HE missions: Adaptation to Climate Change,
- the HE missions: Healthy Oceans, Seas, Coastal and Inland Waters,
- the HE missions: Soil Health and Food.

Based on the identified complementarity and interaction of the BIOEAST Vision for 2030, long-term goals, Strategic Thematic Areas, and the EU's main strategies and action plans, one can expect that implementing the BIOEAST SRIA will add value to the following EU's aims and strategies: Sustainable bioeconomy for Europe, Farm to Fork Strategy, EU Biodiversity Strategy for 2030, EU Pollinator Initiative, New EU Forest Strategy for 2030, New Industrial Strategy for Europe, an EU Strategy for Energy System Integration, the new EU Strategy on Adaptation to Climate Change, 2030 Climate Target Plan, New Circular Economy Action Plan.

Since the EU's strategies (Sustainable bioeconomy for Europe, Farm to Fork Strategy, EU Biodiversity Strategy for 2030, New EU Forest Strategy for 2030, New Industrial Strategy for Europe, an EU Strategy for Energy System Integration, the new EU Strategy on Adaptation to Climate Change, 2030 Climate Target Plan) and the New Circular Economy Action Plan are subordinate to the European Green Deal, the BIOEAST SRIA also establishes links with the European Green Deal.

