BIO east

STRATEGIC RESEARCH AND INNOVATION AGENDA

BIOEAST.EU

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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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FOREWORD

In 2016, during the Slovak EU Presidency and the Polish Visegrad 4 Presidency, seven ministers signed a common declaration on stronger inclusion of the research potential of Central and Eastern European (CEE) countries into the implementation of projects within Horizon 2020 in the field of agriculture, including the bioeconomy. This triggered joint strategic work on aligning research priorities. Since then, cooperation in developing a common understanding on research priorities has become the most important foundation of the BIOEAST Initiative. The Initiative grew from seven to eleven countries, with an observer from the Western Balkans, as it began to become clear that without building a common understanding of the bioeconomy, success in research and innovation would not be achieved. A systemic approach was required to deploy knowledge-based agriculture, forestry and aquaculture in the context of a sustainable and circular bioeconomy, both at national and regional levels. This has led to further steps being taken to develop strategic thinking in the bioeconomy.

The BIOEAST Initiative set the objective of building a common strategic research and innovation agenda (SRIA) in order to highlight the common needs and priorities of the CEE macro-region. The specific objective of this work is to emphasise the necessity of tackling the bioeconomy within its complexity and to link and, where possible, start new cross-sectoral value chains.

Today, we are facing challenges related to climate change, health and recent geopolitical events. The macro-region has also been severely affected by droughts, the COVID-19 pandemic and supply chain disruptions. A strategic agenda is required to focus on the most important future steps. Research and innovation priorities and actions will impact our future for decades. With limited financial capacities, the countries require accurate priority setting and focused decisions. In this context, the BIOEAST SRIA aims to draw the attention of policymakers to key priorities.

There are two interlinked answers to the question of why a macro-regional agenda is necessary, even though the European Union's (EU) priorities are the commonly agreed priorities for all Member States. First, the SRIA development requires an exercise that has value in and of itself. Building a network of stakeholders at the national and macro-regional levels, discussing common priorities and participating in thematic discussions in the region sets the foundation for a long-lasting framework that can replicate strategic planning and collaboration exercises. Second, strongly deliberated EU-level discussions and well-funded EU collaborative research actions require thoroughly developed national and macro-regional priorities, especially considering the sustainability issues that often require collaboration across Member States and climatic regions. Therefore, the value of this document lies not only in setting macro-regional priorities but in setting a reproducible exercise that can contribute to EU discussions.

The EU Member States need to cooperate more than ever to better use resources and cope with crises. Climate neutrality cannot be achieved without sustainable bioeconomy. The future competitiveness of the EU and its Member States depends on research and innovation advancements. Thus, the strategy development processes should not be thought of as an encumbrance but rather as recognition that those who will act sooner will face the benefits earlier in a highly competitive environment. The EU has set an ambitious climate and green agenda, but significant investment in research and innovation is needed. In some countries, especially in those involved in the BIOEAST Initiative, the focus should also be on specific investments in knowledge transfer, which also requires research and innovation to strengthen local and regional transition and adaptive capacity to changes in the environment. Knowledge transfer, transition and adaptation are not prominent priorities of the Horizon Europe agenda. The BIOEAST macro-region of CEE countries should be connected to the European Research Area through excellence in science, along with knowledge transfer, transition and adaptation.

The excellence-based knowledge of Horizon Europe should be transferred and adapted to the needs of these regions to help the development of EU sovereignty in the bioeconomy, including food and energy security.

The BIOEAST SRIA was developed around pre-agreed core thematic areas, including agroecology and sustainable yields, food systems, the forestry value chain, a fresh water-based bioeconomy, bioenergy and value-added materials, advanced biochemicals and biomaterials, and bioeconomy education and skills. The SRIA outlines the main challenges, research areas and expected outcomes in each of these core thematic areas.

The SRIA was created with the support of the consortium established by the Horizon 2020 project BIOEASTsUP, and through stakeholder engagement that involved policy makers, researchers and actors from both the private and public sectors. The development process was supervised by the member ministries of the Initiative, its advisory council and Thematic Working Groups, which included representatives from the public sector and academia. The BIOEAST Board hopes that by using this document they can contribute to setting national agendas and to the EU strategic programming processes.

The Board would like to extend its sincere gratitude to all those who participated in the development of this document, including Ants-Hannes Viira from the Estonian University of Life Sciences, Aleksejs Nipers from the Latvia University of Life Sciences and Technologies, Polish colleagues from the Institute of Agricultural and Food Economics, Hungarian colleagues from the Institute of Agricultural Economics and the coordinators of the BIOEAST Thematic Working Groups. This SRIA was a co-creation effort by multiple entities and represents a significant collaboration effort between the representatives of eleven CEE countries.

BARNA KOVÁCS

BIOEAST Secretary General

ABBREVIATIONS

BECCS – bioenergy with carbon capture and storage

BERD – Business Expenditures on Research and Development

BG – Bulgaria

BIOEAST – The Central–Eastern European Initiative for Knowledge–based Agriculture, Aquaculture and Forestry in the Bioeconomy

BIOEASTsUP – Horizon 2020 project 'Advancing Sustainable Circular Bioeconomy in Central and Eastern European countries'

B2B – business–to–business

B2C – business–to–consumer

CAP – Common Agricultural Policy

CCUS – Carbon capture, utilisation and storage

CEE – Central and Eastern Europe

CO_2 – Carbon dioxide

CSA – Coordination and support action

CZ – Czechia

DataM – Data Portal of Agro–economics Modelling

DG AGRI – the Commission's Directorate–General for Agriculture and Rural Development

DG RTD – the Commission's Directorate–General for Research and Innovation

EE – Estonia

EMÜ – Estonian University of Life Sciences

ERA – European Research Area

EU – European Union

EUR – the euro

FES – Forest ecosystem services

GDP – Gross domestic product

GERD – Gross expenditure on research and development

GHG – greenhouse gases

GOVERD – Governmental intramural expenditure on research and development

GVA – gross value added

GVC – global value chains

H2020 – Horizon 2020

HR – Croatia

HU – Hungary

IT – Information technology

kgdm – kilograms of dry matter

LBTU – Latvia University of Life Sciences and Technologies

LT – Lithuania

LV – Latvia

O – objective

PES – Payment for ecosystem services

PL – Poland

R&D – Research and development

RDI – Research, development and innovation

R&I – Research and innovation

RO – Romania

RT – Main research topic

SC2 – Horizon 2020 Societal Challenge 2 'Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy'

SI – Slovenia

SK – Slovakia

SRIA – Strategic Research and Innovation Agenda

SWOT – Strengths, weaknesses, opportunities and threats

TA – strategic thematic area

tdm – tonnes of dry matter

TWG – Thematic Working Group

Vs – versus

1 THE BIOEAST INITIATIVE AND ITS VISION

1.1. The vision and long-term objectives of the BIOEAST Initiative

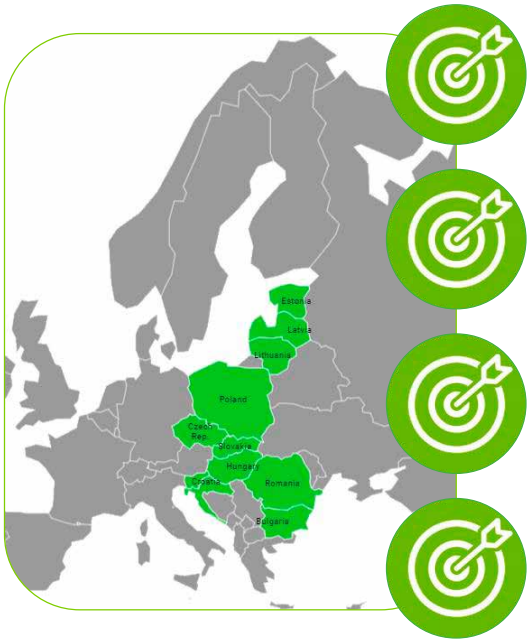
The BIOEAST Initiative was established in 2015 with the ambition of unlocking the bioeconomy potential of the Central and Eastern European (CEE) region. Pursuing this goal requires strengthening the knowledge base, research and innovation excellence, strategic planning, governance and cross-sectoral cooperation in the countries participating in the BIOEAST Initiative. Furthermore, it requires integration with leading European and international initiatives in the broad field of the bioeconomy.

A key milestone of the BIOEAST Initiative is its Vision for 2030[1], which was prepared in cooperation with the European Commission (DG RTD, DG AGRI) and approved by the governments of 11 countries participating in the BIOEAST Initiative. This concisely presented **vision** draws a picture of the BIOEAST region in 2030 as

'a network of cooperating bioeconomy clusters combining conventional (bioeconomy) industries with innovative bio-based technologies'.

The BIOEAST vision is complemented with four **long-term goals** (Figure 1).

Figure 1: **The BIOEAST Initiative long-term goals**



G 1.1. Productivity: Sustainable increase of biomass production, by becoming competitive and leading high-quality food and feed producers that are recognised worldwide.

G 1.2. Sustainability: Developing biodiversity and biosecurity, by maintaining and strengthening natural values and defending the rest of Europe from transboundary plant and animal diseases.

G 2.1. Resource efficiency: Circular and value-added use of the available biomass, by becoming key players in the development of new bio-based value chains.

G 2.2. Rural development: Increasing the viability and attractiveness of rural areas and society, by developing an innovative, inclusive, climate-ready and sustainable bioeconomy growth model by 2030.

Source: BIOEAST, 2018.

[1] BIOEAST. 2018. BIOEAST Vision paper. Available at: https://bioeast.eu/download/bioeast_vision_paper_23022018/

The **scope** of the BIOEAST Initiative builds on background analysis, which reveals a generally low level of bioeconomy maturity in the macro-region. To unlock bioeconomy potentials in terms of jobs, growth, resource efficiency and rural development, accelerated *growth of bioeconomy related research and innovation activities* is required. This includes a *faster development and adoption of scientific and technological advances* for sustainable, circular, climate-ready practices in the primary sector (agriculture, aquaculture and forestry), as well as improved performance and overall *sustainability* of their upstream and downstream sectors. Through *collaborative actions*, it is important to bridge the gap with the leading European regions in the development of new bio-based value chains, environmental protection and sustainable resource management. The **intervention** of the above actions needs to consider various **territorial levels** – from European, to macro-regional, sub-regional, national and regional/local levels.

The BIOEAST Vision for 2030 paves the way for the comprehensive Strategic Research and Innovation Agenda (SRIA) by identifying **five challenges** that hinder the region's performance and therefore require action.

- ***Research and innovation deadlock*** characterised by poor RDI infrastructure and weak links between industry and academia, results in limited uptake and deployment of research results into practice.
- ***Stalemate in the bio-based value chains*** hinders more effective use of biomass in the traditional value chains, as well as the utilisation of opportunities in innovative ones.
- ***Governance impasse*** that derives from difficulties in the integration of the multidisciplinary concept of bioeconomy with sectorally-oriented public policies.
- ***Societal indifference*** towards the concept of circular bioeconomy.
- ***Financial barriers,*** characterised by generally low access to finance and the low level of public-private endeavour in pooling resources on RDI in the BIOEAST macro-region.

Seven broad fields of action are set to address the challenges:

1. **Develop strategies:** to create a cross-sectoral approach for the development of national circular economy and bioeconomy strategies in all countries of the CEE region aligned to the EU bioeconomy strategy and the common BIOEAST Initiative goals.
2. **Cooperate and develop evidence-based policies:** to establish a multi-stakeholder network and cluster under the BIOEAST Initiative to facilitate joint actions, backed up by a renewed commitment to closer cooperation at both political and operational levels.
3. **Identify common challenges and validate common research areas:** to map specific challenges for the BIOEAST SRIA and foster innovative and multidisciplinary RDI cooperation at national and macro-regional levels. These should address the common challenges of the BIOEAST Initiative member countries by means of common work carried out by experts, researchers and governmental officers as a follow-up to the Visegrad 4+3 Common Declaration[2] and provide a starting point for further discussions.
4. **Provide the evidence base:** to map and establish data-driven support for the development and implementation of bioeconomy-related policies through the creation of an interoperable, fully-integrated monitoring and projection system. This would support a continuous, long-term evidence base for bioeconomy development.
5. **Improve skills:** to increase the expertise of the actors involved by means of training and capacity building actions.
6. **Develop synergies:** to promote regional, national, EU and international funding opportunities for the development of innovative technologies, methodologies and approaches to boost the sustainable economic growth of the European bioeconomy and circular economy sectors as well as the conservation and upgrading of the regional environment, resources and cultural heritage.

[2] Visegrad Group. 2023. Official Statements and Communiqués https://www.visegradgroup.eu/documents/official-statements

7. **Increase visibility:** to draw attention to specific challenges and to the research and innovation potential of the macro-region, through involving the society and promoting public awareness.

Seven Thematic Working Groups (TWG) are operating within the BIOEAST Initiative as a lasting macro-regional thematic network, and these are represented by nationally nominated representatives of ministries, academia and industry:

1. Agroecology and Sustainable Yields,
2. Forestry Value Chains,
3. Food Systems,
4. Bioenergy and New Value-added Materials,
5. Advanced Biochemical and Biomaterials,
6. Freshwater Based Bioeconomy,
7. Bioeconomy Education.

The aim of the TWGs is to strengthen the European Research Area (ERA), to create synergies between the different countries' researchers, RDI needs/topics and to connect relevant organisations in the BIOEAST macro-region (public administration, RD& organisations, industry) to the EU bioeconomy networks.

1.2. BIOEAST's contribution to sustainable and inclusive growth for Europe

The BIOEAST Initiative and the BIOEAST macro-region will contribute to achieving the EU's long-term goals set in the European Green Deal[3] through addressing the five challenges specified in the BIOEAST Vision for 2030 (Figure 2). Likewise, the BIOEAST Foresight Exercise[4] pointed out that the circular bioeconomy is an enormous opportunity for the growth of the BIOEAST region. The activities of the BIOEAST Initiative will help to:

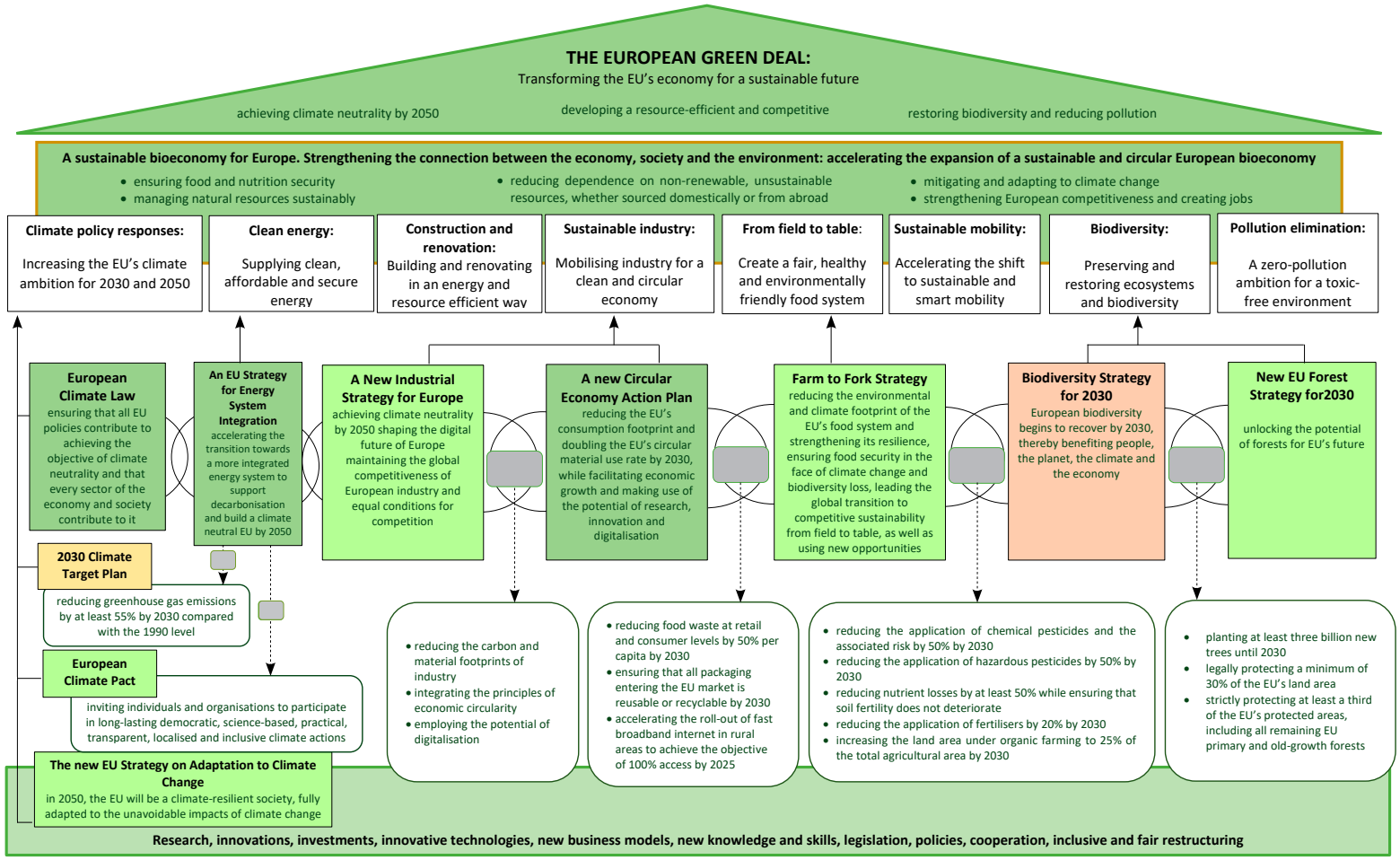
- promote the development of a knowledge-based circular bioeconomy in the CEE countries;
- make European industries greener, more circular and more sustainable;
- make Europe climate neutral; mitigate and adapt to climate change;
- enhance the competitiveness of the BIOEAST macro-region and create new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

Furthermore, the bioeconomy offers the opportunity to develop new value chains and business models, which could attract private and public investments in improved management practices; e.g., to increase the resilience of forests to climate change, or to support 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 that have better resistance to pests and plant diseases, thereby responding to climate change more effectively. Additionally, digitalisation is an enabler of a more rapid transition to a circular bioeconomy, and data economy.

[3] European Commission. 2019. The European Green Deal. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN

[4] BIOEAST Foresight Exercise Group of Experts. 2021. BIOEAST foresight exercise report (Deliverable 3.4.).

Figure 2: **The European Green Deal and the long-term objectives of the underlying policies**



To visualise the potential impacts of the BIOEAST initiative on the EU's strategies and action plans, it was assumed that:

If all the four BIOEAST long-term goals are complementary to the EU's strategies and action plans, the contribution of the BIOEAST initiative to the EU's priorities could be considered **very significant**	If three of the four BIOEAST long-term goals are complementary to the EU's strategies and action plans, the contribution of the BIOEAST initiative to the EU's priorities could be considered **significant**	If two of the four BIOEAST long-term goals are complementary to EU's strategies and action plans, the contribution of the BIOEAST initiative to the EU's priorities could be considered **moderate**	If one of the four BIOEAST long-term goals are complementary to EU's strategies and action plans, the contribution of the BIOEAST initiative to the EU's priorities could be considered **insignificant**

- common targets and measures of policies

Source: author's construction based on the EU strategies and action plans examined.

2 STATE-OF-THE ART

2.1. Bioeconomy in the BIOEAST macro-region

The BIOEAST macro-region includes eleven CEE countries (Bulgaria, Czechia, Estonia, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia) with more than 102 million inhabitants (which accounted for 25% of the total population in the EU countries in 2020) and 1 135 290 km^2 of area (which accounted for 25% of the EU area). In terms of population, the largest countries are Poland, Romania and Czechia, whereas Estonia, Latvia and Slovenia have the smallest populations. By country area, the largest countries in the BIOEAST macro-region are Poland, Romania and Bulgaria while the smallest are Slovenia, Estonia and Slovakia.

The trade in intermediate products can provide important insights into how countries are integrated into global value chains (GVC)[5]. Countries can be involved in GVCs in different ways. Those that produce at the beginning of the production chain (upstream) import fewer intermediate goods and services, but they export more of them than countries that are located at the end of the chain (downstream). Thus, countries can participate in GVCs by using foreign inputs in exports (backward participation), or they can be suppliers of intermediate goods and services that are further used in other countries' exports (forward participation).

Figure 3 shows countries clustered by the share of intermediates in exports and imports[6]:

- **Small open economies**: Countries characterised by the above average share of intermediate goods, both in total exports and total imports. These countries are highly integrated in the GVCs.
- **Assembly countries**: Typical for countries with large assembly plants with the share of imported intermediates higher than the average, while the share of intermediates exports is lower than the average. Slovakia and Hungary belong to this group of countries.
- **Domestic market driven**: Countries where intermediates account for a lower than average share of imports and exports. For these countries, the emphasis is on final products trade. Croatia belongs to this group of countries.
- **Raw materials exporters**: Countries where the share of intermediates of total imports is lower, but where total exports is higher than the average of all countries. Typically, resource rich countries belong to this group.

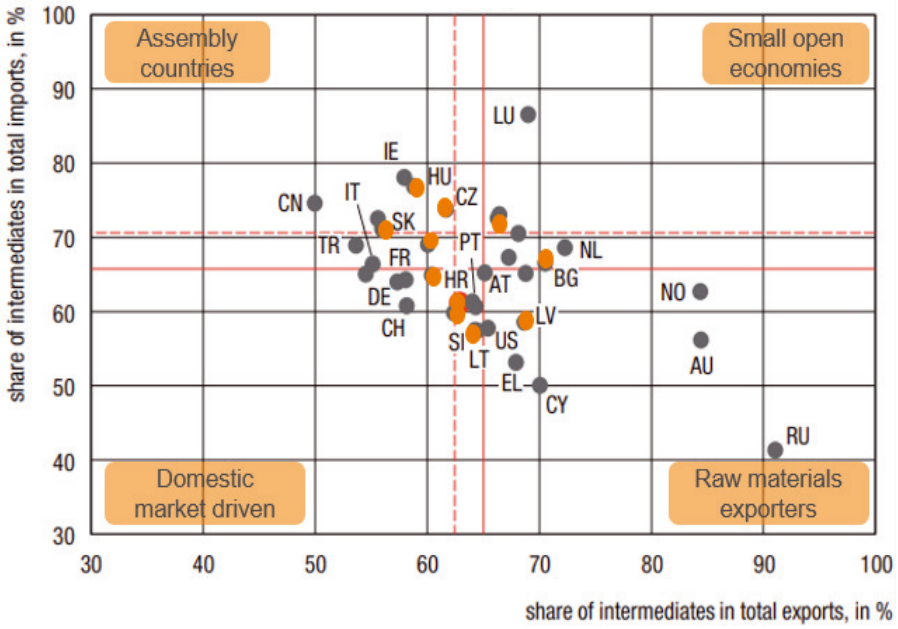
The best way for Czechia, Estonia, Croatia, Hungary, Latvia, Lithuania, Romania, Slovakia and Slovenia to prosper would be to adopt a range of positions between assembly countries and small and open economies. Although Poland and Romania have the capacities to prosper based on their domestic markets, their lower purchasing power parity than the EU average will not allow for similar prosperity as in those EU countries with a higher standard of living (e.g., Germany, France, Sweden) and with a similarly sized domestic market. The option for Romania and Poland would be to combine the small open economies approach until the purchasing power of

[5] Ahmad, N., Bohn, T., Mulder, N., Vaillant, M., Zaclicever, D. 2017. Indicators on global value chains, OECD Statistics Working Papers 2017/08

[6] Peruško, I.V., Kovač, K., Jošić, M. 2018. Croatia in Global Value Chains. Surveys S-32, Croatian National Bank. Zagreb.

their internal markets increases before then transitioning to becoming domestic market driven countries.

Figure 3: **Position of the BIOEAST countries within Global Value Chains**



Note: Solid red lines refer to the means for all countries, and the dashed red line refers to the means of the CEE countries.
Source: Peruško et al., 2018.

JOBS AND VALUE ADDED

The bioeconomy of the BIOEAST macro-region employed around 7.1 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. Agriculture combined with food, beverage and tobacco manufacturing provide 66.6% of the total value added generated by the bioeconomy sectors.

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**

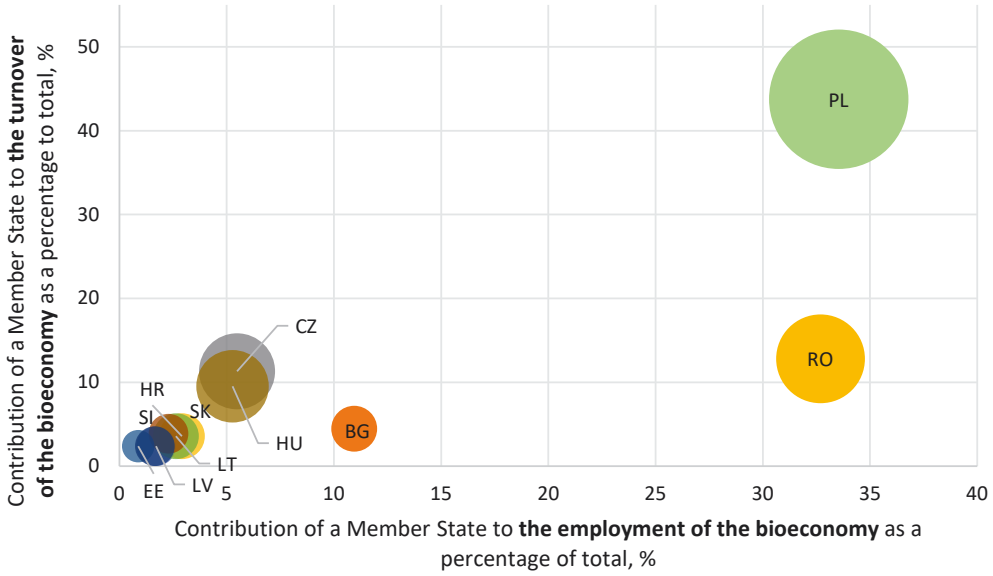
Value added per person employed in biomass producing and converting sectors, thousand EUR			
	BIOEAST macro-region	EU	
	13	**38**	

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.

As regards the distribution of the **bioeconomy value added** across the BIOEAST countries, Poland's contribution was the largest and accounted for 38.5% of the total BIOEAST macro-region's value added in 2019 (Figure 4). Romania, Czechia and Hungary were also significant contributors, generating 15.6%, 11.5% and 10.4% of the macro-region's value added, respectively. The seven remaining BIOEAST countries individually contributed less than 5%. Poland and Romania provided two thirds of the **bioeconomy workforce** in the BIOEAST macro-region, each of them contributing about 33%. Bulgaria was also a significant contributor: its contribution accounted for more than one tenth of the bioeconomy employment in this macro-region. Each of the remaining BIOEAST countries contributed 5.5% or less.

Figure 4: **Contributions of the BIOEAST countries to the turnover, employment and value added of the bioeconomy as a percentage of total in the BIOEAST macro-region in 2019**



Contribution of a Member State **to the value added** of the bioeconomy as a percentage of the BIOEAST macro-region's total, %

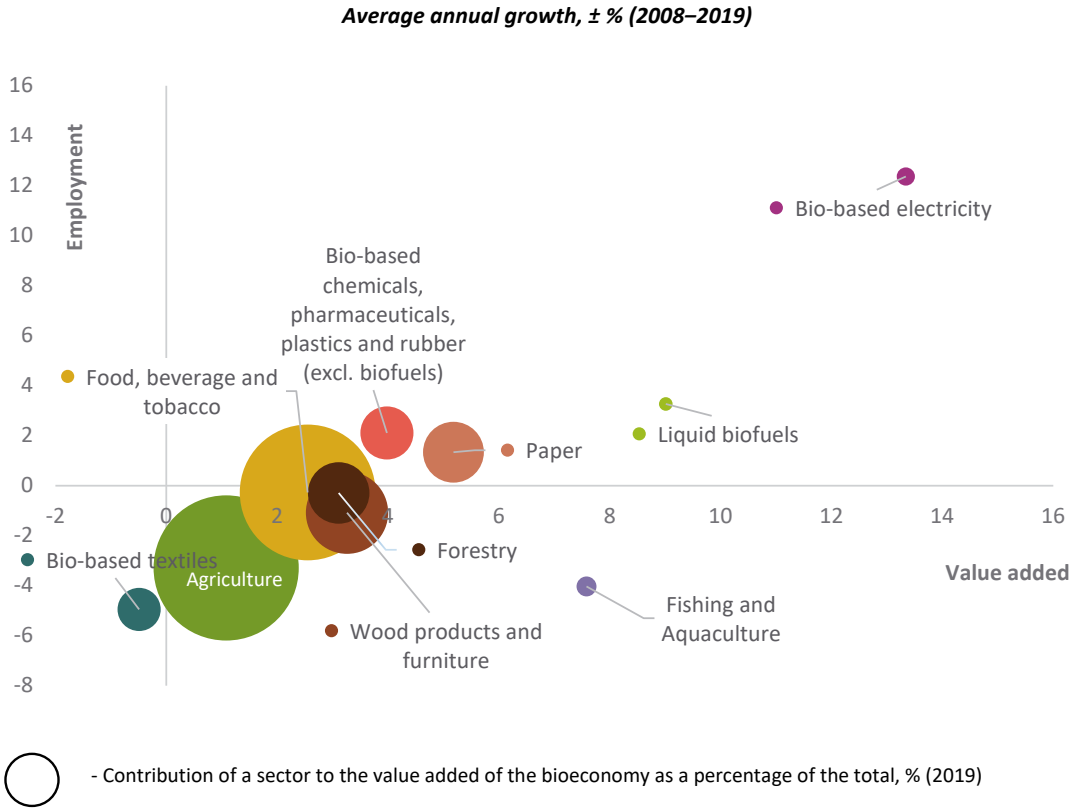
PL	RO	CZ	HU	BG	HR	LT	LV	SI	SK	EE
38.5	15.6	11.5	10.4	4.2	4.2	4.2	3.1	3.1	3.1	2.1

Source: Joint Research Centre, 2022.

In the BIOEAST macro-region, the total value added of bioeconomy sectors increased by EUR 20.6 billion (27.9%) in the 2008–2019 period. The largest increases occurred in the manufacturing of food, beverage and tobacco (+ EUR 7.1 billion), agriculture (+ EUR 3.7 billion) and the manufacturing of wood products and furniture (+ EUR 3.2 billion). However, the manufacture of bio-electricity and liquid biofuels, fishing and aquaculture were the most dynamic sectors with growth of 296.6%, 158.4% and 123.3%, respectively, over the period.

In the BIOEAST macro-region, the bioeconomy grew at an average annual rate of 2.3% in terms of **value added** during the 2008–2019 period (Figure 5). Across the BIOEAST countries, the highest average growth of the bioeconomy was found in Lithuania (4.9% per year), Latvia (4.0%), Estonia (3.7%) and Poland (3.1%). The slowest growth of the bioeconomy was observed in Romania and Croatia (0.5% and 0.1%, respectively). Among the bioeconomy industries, significant differences in the growth of value added were observed in almost all the reported industries (except for the manufacture of biotextiles). The most rapid average annual growth was recorded in the manufacture of liquid biofuels (9.0%), bio-based electricity (13.3%) and fishing and aquaculture (7.6%), followed by the manufacture of paper (5.2%). In the remaining industries, real value-added growth averaged 4% or less.

Figure 5: **The bioeconomy development trends in the BIOEAST macro-region**



Source: Joint Research Centre, 2022.

In the BIOEAST macro-region, **employment** in the bioeconomy decreased by 2.3 million people between 2008 and 2019. The highest decrease in the number of employed people was observed in agriculture (2.0 million). This declining trend was mainly driven by the ongoing restructuring of the agricultural sector, which was still the main bioeconomy employment sector in all the BIOEAST countries. The average decrease rate of employment in the bioeconomy (during the 2008–2019 period) was 2.5%. An average annual decrease in the number of people employed was observed in agriculture (-3.3%), forestry (-0.2%), fishing and aquaculture (-3.8%), food industry (-0.3%), the manufacture of bio-based textile (-4.8%) and wood products and furniture (-1.0%), while in other bioeconomy industries it increased (bio-based chemicals (2.1%), paper (1.4%), bio-based electricity (13.9%) and liquid biofuels (4.7%)).

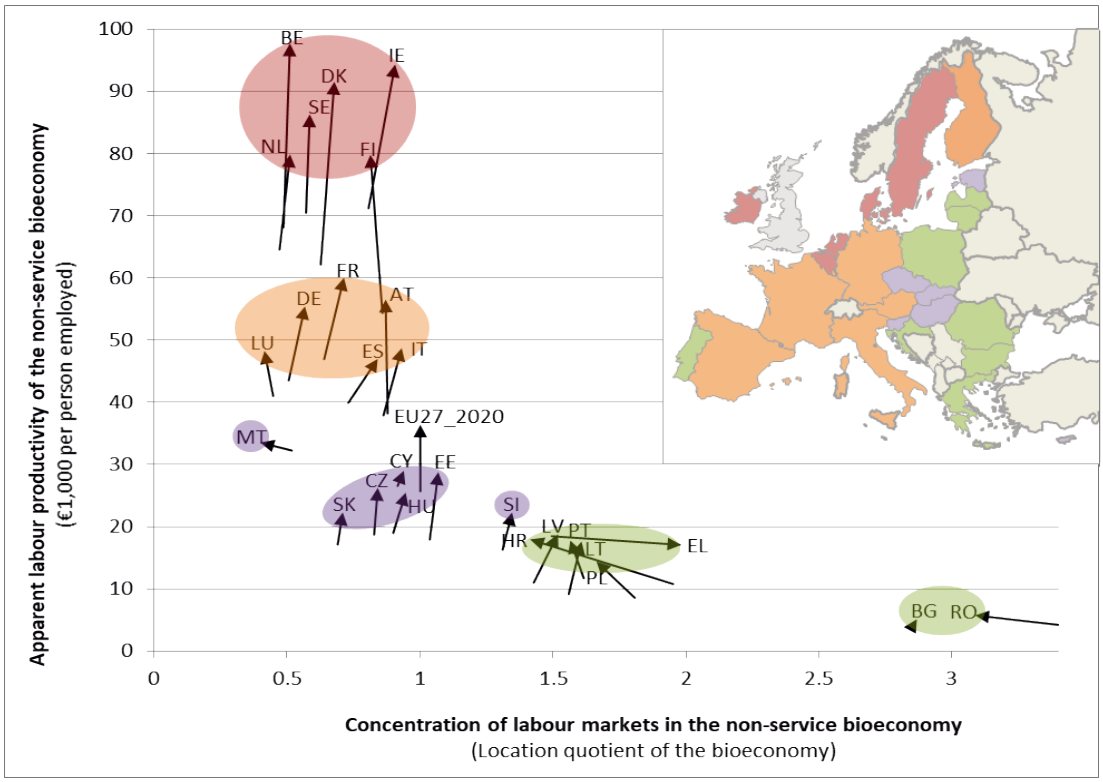
Average **labour productivity** in the bioeconomy of the BIOEAST macro-region was about three times lower than the EU average (Table 1). Such a gap was identified in all the considered bioeconomy industries. Labour productivity varies significantly among reported fully and partly bio-based industries. Labour productivity was highest in the manufacture of bio-based electricity, liquid biofuels and bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) (EUR 104 800, EUR 48 000, EUR 47 700 per person employed, respectively), while the lowest labour productivity was recorded in agriculture and in the manufacture of bio-based textiles as well as wood products and furniture (EUR 7.5 thousand, EUR 12.2 thousand and EUR 18.4 thousand per person employed, respectively).

According to Ronzon et al.[7], based on the bioeconomy employment and labour productivity, the BIOEAST countries were clustered in two groups [8](Figure 6):

1. Green group: characterised by a labour market highly specialised in the non-service bioeconomy and a below-average apparent labour productivity of the non-service bioeconomy (≤ half the EU27 labour productivity) (**Bulgaria, Romania, Latvia, Lithuania, Poland, Croatia**);

2. Purple group: characterised by a labour market less specialised in the non-service bioeconomy, but more labour productive (labour productivity between half the EU's) (**Hungary, Czechia, Slovakia, Estonia, Slovenia**).

Figure 6: **Bioeconomy patterns across EU-27 Member States in 2008-2010 and 2017-2019**



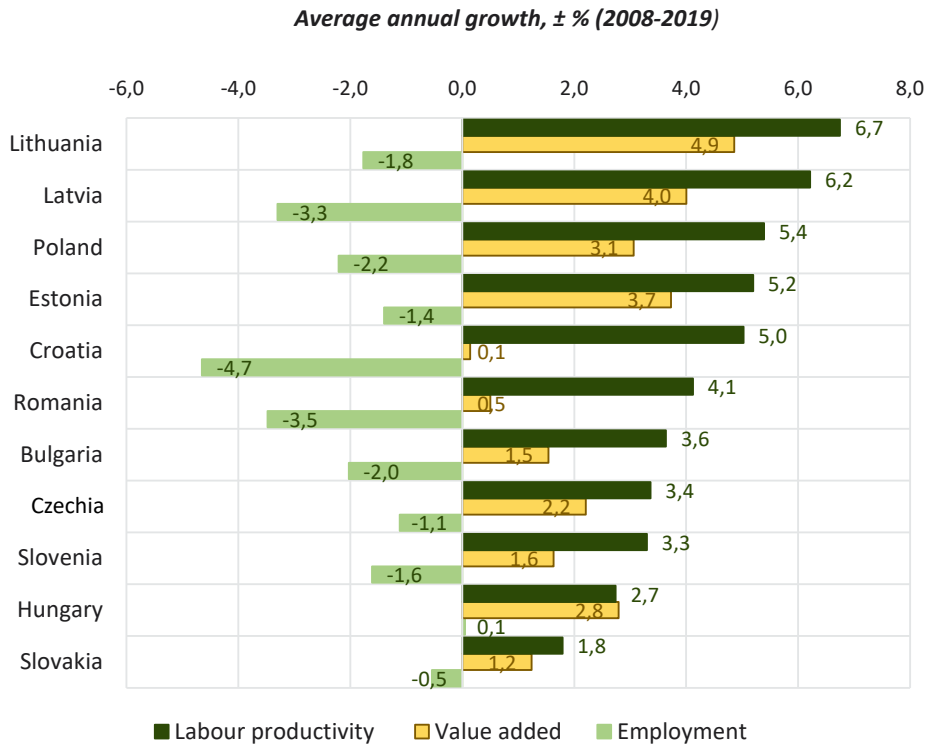
Source: European Commission, 2022b.

Individual trajectories are illustrated with arrows in Figure 6, with the starting points of arrows referring to the positions of Member States in 2008-2010 and the end points referring to their position in 2017-2019. During the 2008-2019 period, the labour productivity of the bioeconomy sectors improved in the BIOEAST macro-region. The highest labour productivity growth compared to the base year was reported in Lithuania (105.1%), Latvia (94.1%), Poland (78.2%), Estonia (74.6%) and Croatia (71.5%). The same BIOEAST countries also reported the highest average growth over the 2008-2019 period (Figure 7).

[7] Ronzon T, Piotrowski S, Tamosiunas S, Dammer L, Carus M, M'barek R. 2020. Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU. Sustainability. 12 (11, 4507):1-13. doi.org/10.3390/su12114507

[8] European Commission. 2022. The bioeconomy in different countries. Available at: https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries

Figure 7: **The bioeconomy development trends in the BIOEAST countries**



Source: Joint Research Centre, 2022.

It follows that the bioeconomy in the BIOEAST macro-region is concentrated in traditional sectors, as well as in low technology and low-productivity industries.

During the 2008-2019 period, the total value added of the bioeconomy increased (average annual growth by 2.3%) in the BIOEAST macro-region, whereas total employment in the bioeconomy decreased (average annual decrease by 2.5%). However, the decrease in employment has not occurred in all the sectors of the bioeconomy. In the 2008-2019 period, employment increased in sectors such as the production of bio-based electricity, liquid biofuels, bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) and paper, and in these bioeconomy 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.

BIOMASS SUPPLY IN THE BIOEAST MACRO-REGION

The **total supply of biomass** in the BIOEAST macro-region amounted to approximately 346 million tonnes of dry matter (hereinafter tdm) (latest available data, mentioned in the text accordingly) (Figure 8). Of the total biomass, 80.4% was produced in the BIOEAST countries, 11.2% of the biomass was imported and the origin of 8.4% of the total biomass could not be identified. The relatively largest biomass importing countries among the BIOEAST countries are Slovakia, Slovenia and Croatia, where the share of imported biomass exceeds 20% of the total supply of biomass. In contrast, the relatively largest biomass producing countries in the BIOEAST macro-region are Poland, Hungary, Bulgaria and Estonia, where the share of produced biomass in the total supply of biomass exceeds 80%.

The agricultural sector is the largest producer of domestic biomass with 79% of the total in the BIOEAST macro-region (ranging from 25% in Estonia to more than 80% in Poland, Hungary, Romania and Bulgaria), followed by forestry with 21% of the dry matter content (from 4% in Poland

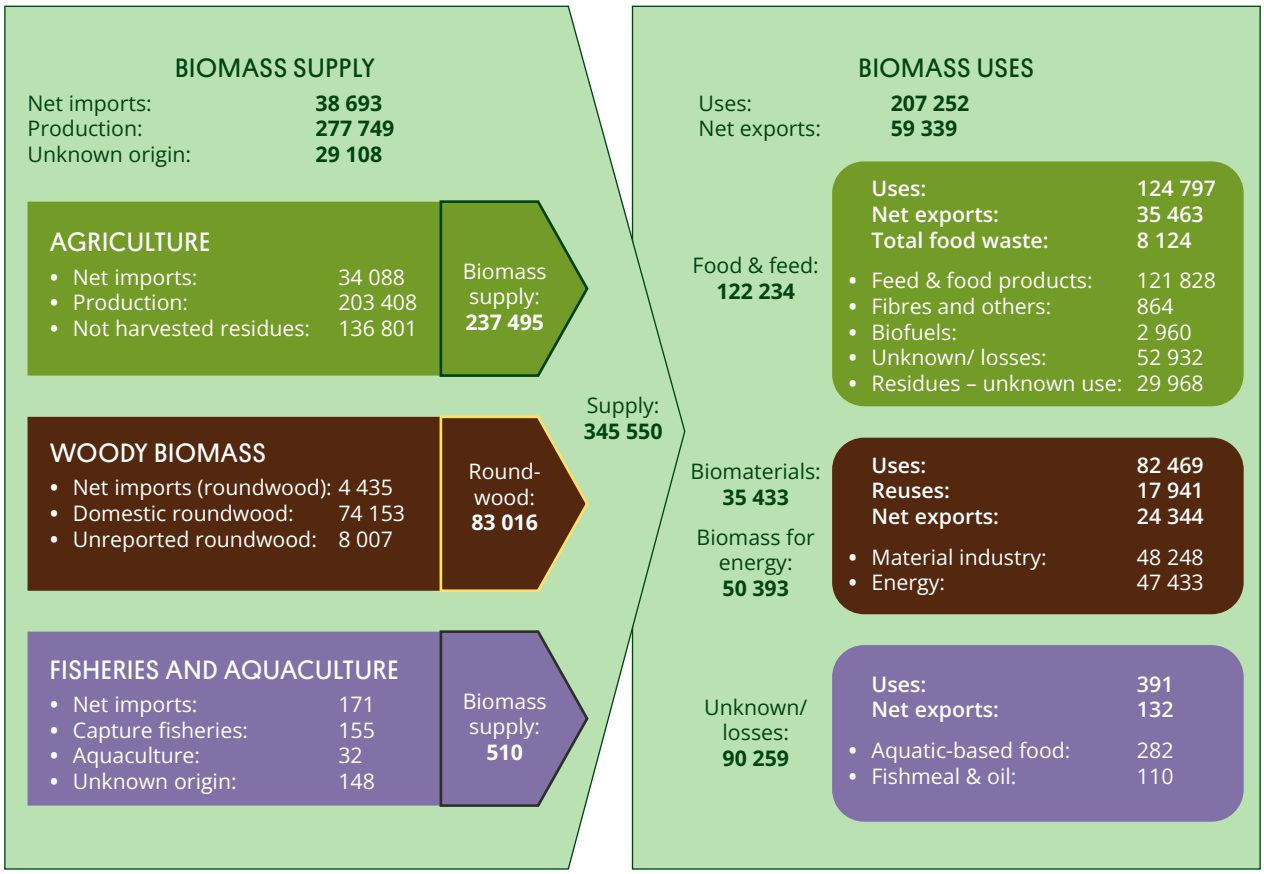
to more than 60% in Latvia and Estonia). The proportion of the fishery sector is quite small (less than 1%).

In 2018, the BIOEAST macro-region's agricultural biomass total supply (in net trade figures) amounted to approximately 237 million tonnes of dry vegetal biomass equivalents (33% of the total EU agricultural biomass supply). The main sources of agricultural biomass are crop production (59%) and harvested crop residues (16%). 25 million tonnes of biomass are grazed in pastures and meadows. Romania and Poland have the highest supply of agricultural biomass in the BIOEAST macro-region. Romania, Czechia and Slovakia are the largest net importers of agricultural biomass (Figure 1 in Annex 1).

The BIOEAST macro-region's supply of roundwood was estimated at approximately 83 million tdm in 2017, of which at least 89% was sourced domestically. In the BIOEAST macro-region, the biggest producer of roundwood is Poland, followed by Czechia, Romania and Latvia (Figure 2 in Annex 1). The total net imports of all woody biomass types are estimated to be approximately 4.4 million tdm (Figure 8).

The BIOEAST macro-region's production of seafood by capture fisheries and aquaculture was approximately 187 thousand tdm in 2016 with 155 thousand tdm originating from capture fisheries and 32 thousand tdm from aquaculture. The net imports of seafood products amounted to approximately 171 thousand tdm, i.e., almost as much as produced in the entire BIOEAST macro-region (Figure 8). Poland, Lithuania and Latvia have the highest supply of seafood in the BIOEAST macro-region. Poland, Romania and Czechia are the largest net importers of seafood products, while Estonia, Croatia, Latvia and Lithuania do not import this kind of biomass at all (Figure 3 in Annex 1).

Figure 8: **Biomass flows by sector for the BIOEAST macro-region in 1 000 tonnes of dry matter, in net trade figures, latest available data**



Source: DataM, 2022b.

BIOMASS USES IN THE BIOEAST MACRO-REGION

In most of the BIOEAST countries, as well as in the macro-region, food and feed are the most important category in terms of biomass use. In Latvia and Estonia, biomass for energy is the most important category in terms of biomass use.

Most of the BIOEAST countries (except Estonia, Latvia, Poland and Slovenia) have a large proportion (>30%) of losses or biomass for which a specific use cannot be estimated (Figure 4 in Annex 1). If the losses or biomass for which a specific use cannot be estimated are not considered, approximately 59% of the available biomass is used for food and feed, with biomass for energy and biomaterials accounting for 24% and 17% of the identified biomass uses, respectively.

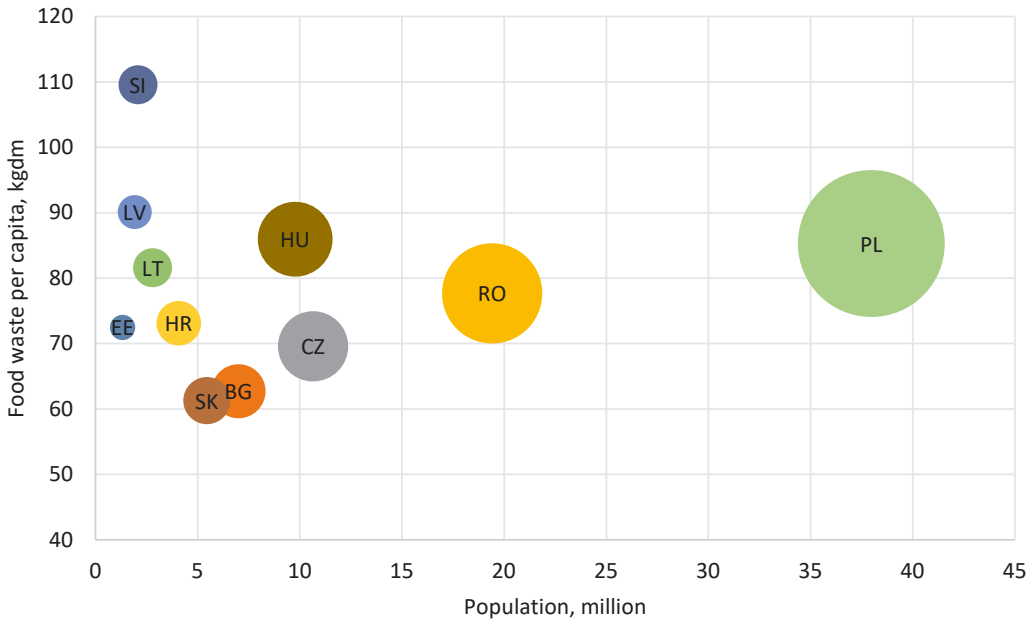
The biomass used for food and feed products is almost entirely of agricultural origin. 51% of the total agricultural biomass supply was used as food and feed in 2018. 79% of the total biomass for food and feed uses is utilised as animal feed and bedding to produce animal-based food (either for domestic consumption or for export), while the rest is directly consumed as plant-based food or is food wasted before consumption (vegetal biomass at the processing and manufacturing stage). Within the BIOEAST macro-region, Poland (48 million tdm) and Romania (23 million tdm) were the biggest producers of food and feed (Figure 5 in Annex 1).

Just 0.2% of the biomass dry matter that is used for food and feed is of aquatic origin. This comprises 72% of the biomass supply of fisheries and aquaculture. Poland is the largest producer of aquatic-based food in the BIOEAST macro-region. Poland, Latvia and Lithuania are the biggest manufacturers of fishmeal and oil. The largest net exporting countries are the three Baltic countries (Figure 6 in Annex 1).

Most of the biomass used as energy is woody biomass. In 2017, 47 million tdm of directly or indirectly gathered woody biomass were estimated to have been used for energy in the BIOEAST macro-region. In 2017, approximately 35 million tdm of biomass were used for bio-materials (Figure 8).

Food waste in the BIOEAST macro-region is estimated to be approximately 8.1 million tdm in 2018 (Figure 8). This figure includes waste from household consumption and food services, waste during the processing and manufacturing, as well as retail and distribution stages, and animal-based food waste at the production stage. Vegetal food waste at the production stage has not been included. The BIOEAST countries with the largest populations also produce the biggest amounts of food waste (Figure 9).

Figure 9: **Food waste and population (million) in the BIOEAST countries in 2018**



Source: DataM, 2022b; EUROSTAT, 2022a.

The BIOEAST macro-region's consumers wasted almost 5 million tdm of food in 2018. This is on average 17.5% of the total food available for consumption. In Latvia and Slovenia, most of the food waste (more than 50%) originates at the stages from primary production to distribution. Most of the food waste produced in the EU and in the BIOEAST countries is destined for disposal in landfills, sewage or incineration. Composting and anaerobic digestion are the other two main destinations of food waste. Waste and by-streams from field-to-fork production could be a source for development of novel value chains in the BIOEAST macro-region.

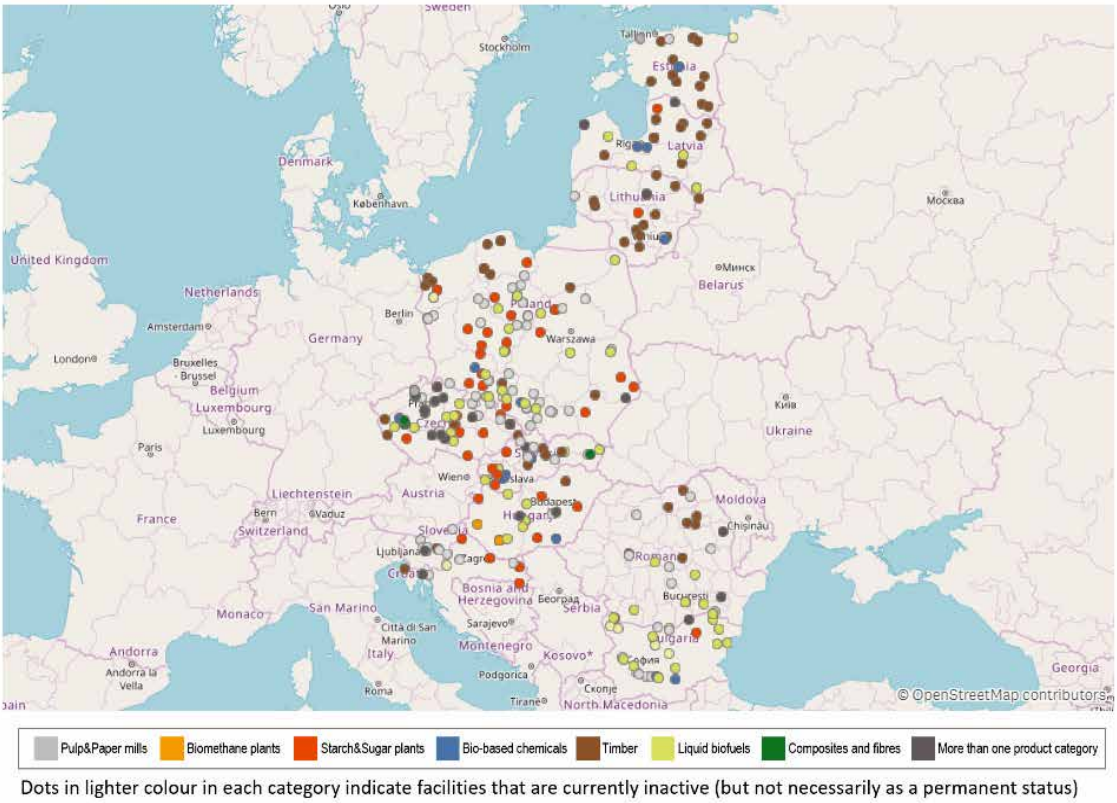
The current bioeconomy players have the advantage of already producing bio-based products but they must still undergo the transition to the circular and sustainable bioeconomy. This includes not only developing new value chains for waste and by-product streams but also using clean energy and improving resource efficiency in the production system.

BIO-BASED INDUSTRY IN THE BIOEAST MACRO-REGION

The Joint Research Centre report data on 314 facilities using biomass for product manufacturing in the BIOEAST macro-region (13% of the EU total). The database includes a wide range of plants, from innovative, recently built biorefineries in which the newest principles of the circular economy are applied, to very traditional, decades-old plants obtaining products from biomass (e.g., some timber, paper or starch plants)[9]. A large portion (43.3%) of bio-based facilities of the BIOEAST macro-region is concentrated in Poland and Czechia (Figure 10). Most of the bio-based facilities (97%) of the BIOEAST macro-region are commercial plants.

9 Parisi, C. 2020. Distribution of the bio-based industry in the EU. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-16408-1, doi:10.2760/745867, JRC119288.

Figure 10: **Map of the distribution of the bio-based industry in the BIOEAST macro-region**



Source: DataM, 2022a.

As shown in Figure 7 of Annex 1 and Table 2, agricultural and forestry feedstocks are the most widely used general feedstock classes in the BIOEAST 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. The fewest bio-based processing facilities were engaged in biomethane production (Table 3).

Table 2: **Number of bio-based processing facilities by product category and feedstock origin in the BIOEAST macro-region and countries**

Product category	BG	RO	PL	HR	LV	LT	SI	SK	CZ	HU	EE	Total
	Feedstock origin: **Agriculture** Total: **140 facilities** (commercial plants – 132 facilities; pilot, demo plants – 8 facilities)											
Starch & sugar	1	2	21	3	1	3	1	4	10	8		54
Bio-based composites and fibres			1				1		3			5
Pulp & paper									1			1
Bio-based chemicals	2	3	3		3	1	1	3	11	2	1	30
Liquid biofuels	15	8	15	1	7			7	16	7	2	78
	Feedstock origin: **Forestry** Total: **160 facilities** (commercial plants – 157 facilities; pilot, demo plants – 3 facilities)											
Bio-based composites and fibres								1	1			2
Timber	1	7	13		14	11	2	6	7	1	15	77
Pulp & paper	7	7	37	3		2	7	5	5	2	1	76
Bio-based chemicals					1				3		1	5
Liquid biofuels			2						2			4
	Feedstock origin: **Waste** Total: **20 facilities** (commercial plants – 19 facilities; R&D plant – 1 facility)											
Bio-based composites and fibres				1					5			6
Bio-based chemicals	1		1	1		1		2	1			7
Liquid biofuels	4		2					2		1		9
Biomethane										2		2
	Feedstock origin: **Grasses and Short-rotation Coppice** Total: **2 facilities** (commercial plant – 1 facility; R&D plant – 1 facility)											
Bio-based chemicals						1						1
Liquid biofuels								1				1

Source: DataM, 2022a.

Table 3: **Number of bio-based facilities by product category in the BIOEAST macro-region and countries**

Product category	BG	RO	PL	HR	LV	LT	SI	SK	CZ	HU	EE	Total
Starch & sugar	1	2	21	3	1	3	1	4	10	8		54
Bio-based composites and fibres			1	1			1	1	9			13
Timber	1	7	13		14	11	2	6	7	1	15	77
Pulp & paper	7	7	37	3		2	7	5	6	2	1	77
Bio-based chemicals	3	3	4	1	4	2	1	5	14	2	2	41
Liquid biofuels	17	8	17	1	7			8	17	7	2	**85**
Biomethane										2		2
Total	28	24	**91**	8	24	17	11	28	**45**	19	19	**314**
Number of bio-based facilities in commercial plants	28	23	**88**	8	23	16	10	25	**45**	19	18	**301**
Number of bio-based facilities in pilot, demo and R&D plants	-	1	3	-	1	1	1	3	-	-	1	**13**

Source: DataM, 2022a.

CHEMICAL AND MATERIAL DRIVEN BIOREFINERIES IN THE BIOEAST MACRO-REGION

Biorefineries constitute a key element in order to produce fossil-free materials for a climate-neutral future. Chemical and material driven biorefineries produce primary bio-based high-value added chemicals and materials such as cosmetics, pharmaceuticals, food additives and others, high volume chemicals, and materials such as general bio-based polymers or chemical feedstocks (i.e., building blocks)[10].

The database of the Joint Research Centre reports **12** existing chemical and material driven **biorefineries** in the BIOEAST macro-region. Only 4% of the EU chemical and material driven biorefineries (298 biorefineries in the EU) are in the BIOEAST macro-region. Most of the biorefineries (67% or 8 units) of the BIOEAST macro-region are in Czechia, while the other countries – Croatia, Estonia, Romania and Slovenia – account for one chemical and material driven biorefinery each.

In the BIOEAST macro-region, the most frequent pathway among chemical and material biorefineries is represented by pathway B 'One platform (starch) biorefinery using starch crops', which is geographically concentrated in Czechia (3 units). The second most frequent pathway is represented by D 'Two-platform (pulp and spent liquor) biorefineries using woody biomass', which is also geographically concentrated in Czechia (2 units). Other frequent pathways in the BIOEAST macro-region are pathway A (concentrated in Czechia) and C (in Czechia and Slovakia). Overall, in the BIOEAST macro-region, the largest share (92%) of innovative chemical and material biorefineries belong to one of the categories of commercially available pathways (A-D). Figure 11 shows the distribution of biorefineries by pathway on the map and their frequency distribution.

[10] Baldoni, E., Reumerman, P., Parisi, C., Platt, R., González Hermoso, H., Vikla, K., Vos, J., M'barek, R. 2021. Chemical and material driven biorefineries in the EU and beyond. Publications Office of the European Union. ISBN 978-92-76-34252-6, doi:10.2760/8932, JRC124809.

Figure 11: **Distributions of chemical and material biorefineries by pathways in the BIOEAST macro-region**

Pathway[11]	Number	Share, %	Location country and number
A	2	16.7	- Czechia – 2
B	4	33.3	- Czechia – 3 - Romania – 1
C	2	16.7	- Czechia – 1 - Slovakia – 1
D	3	25.0	- Czechia – 2 - Croatia – 1
E	1	8.3	- Estonia – 1
F	-	-	-
G	-	-	-
H	-	-	-
I	-	-	-
J	-	-	-
Total	**12**	**100**	**-**

Legend:

A. One platform (C6 sugars) biorefinery using sugar crops

B. One platform (starch) biorefinery using starch crops

C. One platform (oil) biorefinery using oil crops, wastes and residues

D. Two-platform (pulp and spent liquor) biorefinery using woody biomass

E. Three platform (C5 sugars, C6 sugars and lignin) biorefinery using lignocellulosic biomass

F. Two-platform (organic fibres and organic juice) biorefinery using green biomass

G. Two-platform (oil and biogas) biorefinery using aquatic biomass

H. Two-platform (organic fibres and oil) biorefinery using natural fibres

I. One platform (syngas) biorefinery using lignocellulosic biomass and municipal solid waste

J. Two platform (pyrolytic liquid and biochar) biorefinery using lignocellulosic biomass

Note:
Classes from A-D represent all those pathways that are available commercially. Pathways E-J are those that have not yet reached a commercial scale[12].

Source: DataM, 2022c.

A description of biorefineries available in the database of chemical and material driven biorefineries involves four main structural elements of biorefinery value chains, i.e., feedstock, conversion processes, platform and products (Figure 12). Agricultural feedstock is the most widely used general feedstock class in the BIOEAST macro-region. Czechia has the highest number of biorefineries (5 units) that use agricultural feedstock. Figure 12 shows that the most widely used agricultural feedstock type in the BIOEAST macro-region is represented by starch crops (4 biorefineries) followed by sugar crops (2 biorefineries) and oil crops (1 biorefinery). The most widely used forestry feedstock type in the BIOEAST macro-region is lignocellulosic wood/forestry (2 biorefineries), followed by residues from forestry (1 biorefinery). Forestry-based biorefineries are concentrated in Czechia and Estonia. The relatively small number of waste-based biorefineries can be found in Czechia and Croatia.

The main conversion processes of biorefineries in the BIOEAST macro-region are biochemical (9), other (2) and mechanical (1). The major platforms are C5/C6 sugar (8), starch (4), lignin (2) and oils (2) (Figure 12).

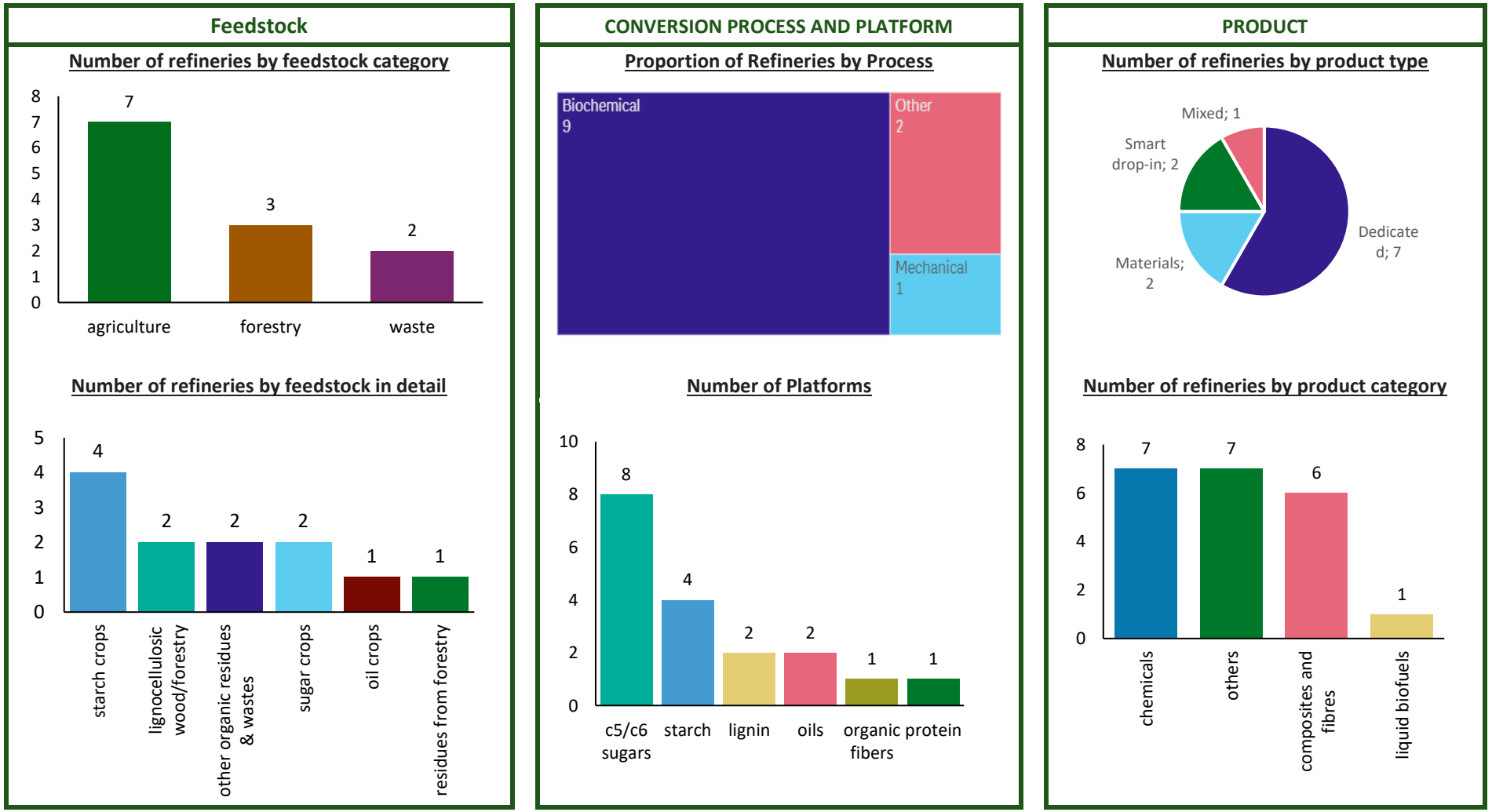
Concerning the distribution of product classes, chemicals and other type of products (e.g., agrochemicals, feed, pharmaceuticals and other bio-based products) seem to be the dominant classes in the BIOEAST macro-region. Composites and fibres are the third most frequent product class across the BIOEAST countries (Figure 12).

11 Each pathway is a combination of one or more Feedstocks, Conversion Processes, Platforms and Products (Platt et al., 2021)

12 Platt, R., Bauen, A., Reumerman, P., Geier, C., Van Ree, R., Vural Gursel, I., Garcia, L., Behrens, M., von Bothmer, P., Howes, J., Panchaksharam, Y., Vikla, K., Sartorius, V., Annevelink, B. 2021. EU Biorefinery Outlook to 2030. DG Research and Innovation of the European Commission - Studies on support to research and innovation in the area of bio-based products and services. Available at: https://www.e4tech.com/biorefinery-outlook.php

It follows from the characteristics of the bio-based industry in the BIOEAST macro-region that the bio-based industry is concentrated in Poland and Czechia. Agricultural feedstock and forestry feedstock are the most widely used general feedstock class in the BIOEAST macro-region. The macro-region is dominated by traditional plants obtaining products from biomass, yet there is a largely untapped potential of biomass side streams. There is a particularly pronounced lack of biorefineries, with the region's capacities accounting to only 4% of the total in the EU.

Figure 12: **Overview of the main structural elements of biorefinery value chains in the BIOEAST macro-region**



Source: DataM, 2022c.

2.2. Regulatory framework and bioeconomy institutional profiles

The EU's bioeconomy strategy 'A Sustainable Bioeconomy for Europe: Strengthening the Connection between the Economy, Society and the Environment'[13] was updated in 2018. Ten EU Member States have adopted a national bioeconomy strategy, of which only one is a BIOEAST country – Latvia. As of 2022, there were seven EU Member States that are in the process of developing their respective strategies, of which four are BIOEAST countries.

Croatia, Czechia, Poland and Slovakia have started the process of developing a national strategy. Other BIOEAST countries (**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'. **Estonia** is preparing a national policy framework document 'Roadmap for the circular bioeconomy', 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.[14] [15]

In Latvia, the National Bioeconomy Strategy was formally adopted in 2017 and was developed as a group effort of the inter-ministerial working group, led by the Ministry of Agriculture (in cooperation with other ministries of various portfolios and the Cross-sectoral Coordination Centre). It was an inclusive process that has been taken on board by non-governmental actors (businesses, NGOs and research institutions).

A review of the cross-sectoral approach and consensus by country[16] shows that in Romania, the bioeconomy has been identified as a priority, but has not yet been recognised by the wider public. A thematic conference on bioeconomy was held in Slovakia. The most common form of organisation for the bioeconomy strategy development was an inter-ministerial working group (Bulgaria, Estonia and Czechia), with science and stakeholder platforms playing an important role. Among the activities, plans under the Rural Development and Circular Economy Programme (Bulgaria, Poland), research projects (Estonia) and participation in international networks such as BIOEAST (Hungary, Lithuania) were crucial to support strategic planning.

From the point of view of the leadership, coordination and sustainability of bioeconomy governance, in most cases either there is no permanent inter-ministerial body or activities are coordinated by one of the ministries. This is most commonly the ministries holding the agriculture portfolio, and in certain cases, those ministries in charge of economy or education and science in the BIOEAST region. With a varied representation of governmental partners, coordination and the linking of activities is a demanding issue. Among stakeholder structures, international networking (e.g. BIOEAST Initiative) is key, as are research and sectoral organisations that, similarly to the ministries, work towards their sector-specific goals; a smaller number are specialised platforms and stakeholder clusters, and these are usually specialised in limited fields of professional interest.

13 European Commission. 2018. A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy. Available at: https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1

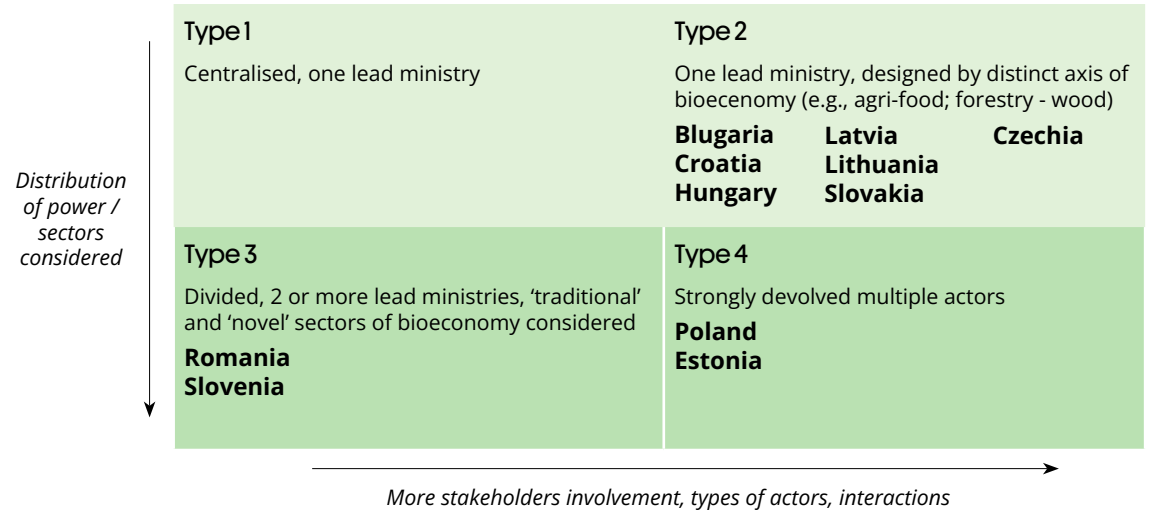
14 European Commission. 2022. The bioeconomy in different countries. Available at: https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries

15 European Commission. Directorate-General for Research and Innovation. 2022. EU Bioeconomy Strategy Progress Report. European Bioeconomy Policy: Stocktaking and future developments: report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-50291-2, doi:10.2777/997651, KI-01-22-230-EN-N.

16 BIOEAST. 2021. Bioeconomy institutional profiles - comparative analysis, benchmarking and policy recommendations (Deliverable 1.4.)

Notwithstanding the BIOEAST countries' formal decision about National Bioeconomy Strategies, some inter-ministerial coordination is taking place, at least as a response to the legally- and institutionally-binding processes at EU level (update/revision of Smart specialisation strategies, National CAP strategic plans). Most often, the agriculture/food sectors are attributed the coordinating role, while other sectors are not strongly integrated into the process. Another noticeable process is integration of the bioeconomy into the strategy-setting process on thematically complementary topics (often mentioned in this respect is the circular economy). The level of knowledge and awareness of the potentials of (a more circular and technologically advanced) bioeconomy at ministerial level in the region is low. There is an understanding of the necessary linkages, which do not, however, manifest at organisational level. At governmental level, this appears especially worrying in terms of the relatively weak integration of science/research/innovation portfolios in the coordination process. Cooperation between institutions is seen as 'useful', but still at the stage of pursuing sectoral-related objectives. The coordination of activities between different government bodies responsible for different bioeconomy-related policies is the key challenge. Successful coordination can strengthen cross-sectoral linkages and give a boost to robust and technologically advanced bio-based value chains. Lack of coordination, on the other side, can cause gaps, or overlaps between different sectoral measures and instruments. Figure 13 illustrates different governance models and institutional mixes in the BIOEAST countries and benchmarking countries.

Figure 13: **Types of governance/ministerial arrangements in BIOEAST countries**



Source: BIOEAST. 2021. Bioeconomy institutional profiles – comparative analysis, benchmarking and policy recommendations (Deliverable 1.4.).

The first governance arrangement group (Type 1 and 2) includes countries where the organisation of bioeconomy issues and delivery of its policy is generally centralised and coordinated by one lead ministry. In countries that apply to Type 1, this is usually a ministry that is not directly linked to the 'traditional' bioeconomy sector, e.g., agri-food and/or forestry-wood sectors. Contrastingly, in the countries of Type 2, the ministry responsible for 'traditional' bioeconomy sectors is usually the key actor in developing and delivering bioeconomy policy. This type applies to most BIOEAST countries (Bulgaria, Croatia, Hungary, Latvia, Lithuania and Slovakia), as the bioeconomy related activities are most commonly coordinated by the agricultural ministry, often combined with the forestry sector.

The second group (Type 3 and 4) incorporates countries where ministries of various portfolios are involved in the governance of the national bioeconomy. Type 3 represents countries where coordination of those activities is divided among different ministries, which govern 'traditional' bioeconomy sectors and 'novel' bioeconomy sectors, e.g., manufacturing of chemicals, pharmaceutical and plastic products. This type applies to Czechia, Romania and Slovenia. In this governance type, different ministries (agriculture and forestry, economy, environment, development and cohesion) coordinate the process of implementing complementary topics (circular economy, decarbonisation, smart specialisation, CAP Strategic Plan). Type 4 has a similar decentralised ministerial distribution. However, more stakeholders, with stronger linkages, are involved in the process of bioeconomy policy delivery. This type applies to Poland and Estonia.

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. First, the review of institutional relations in the BIOEAST and benchmarking countries revealed that the presence of **dedicated and specialised actors**, such as permanent bioeconomy dedicated inter-ministerial bodies, specialised platforms, networks and stakeholder clusters, is pivotal for fostering the development of the bioeconomy. On this matter, there is still much scope for further progress in most countries of the BIOEAST macro-region. In most cases, there is no permanent inter-ministerial body, and among stakeholder structures there is a small number of **bioeconomy specialised actors**. Another crucial factor is the quality of relations between actors and their willingness to engage in **cross-sectoral cooperation**. Currently, the understanding of necessary linkages and cooperation among institutions is present; however, it does not transfer to the organisation level. One of the key challenges at governmental level is the **integration of research and technology development portfolios** in the coordination process.

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 already in the BIOEAST Vision, 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 by adopting the bioeconomy cluster mentality, in which regional feedstock supply, existing industrial infrastructure, know-how and public support are combined.

2.3. Bioeconomy research and innovation in the BIOEAST macro-region

R&D EXPENDITURE AND INTENSITY

BIOEAST is still a lagging region in the EU in terms of R&D investment; however, that gap is decreasing and approaching the EU average. The overall R&D intensity (as a percentage of GDP) in the BIOEAST macro-region rose from 0.9% to 1.2% in the 2010-2019 period vs the increase from 2.0% to 2.2% across the whole EU during the same period. Among the BIOEAST countries, the highest R&D intensity was recorded in Slovenia (2.0%), Czechia (1.9%), Estonia (1.6%) and Hungary (1.5%), while Romania had the lowest ratio of 0.5%, after Latvia 0.6% and Bulgaria 0.8%.

In the BIOEAST macro-region, the Gross Expenditure on Research and Development (GERD) increased considerably in real terms between 2010 and 2019, from PPS 12.7 billion to PPS 24.6 billion euro (at constant 2005 prices), by a compound annual growth rate of 7.1%, compared with 2.9% in the EU. Among the BIOEAST countries, the fastest real growth of the GERD was recorded in Poland (average annual growth 10.4%), followed by Czechia (7.2%), Slovakia (6.9%), Hungary (6.6%), Lithuania and Bulgaria (both 6.1%).

The area where the BIOEAST macro-region lags the most is business investment in R&D and innovation. Even though overall business R&D spending in the BIOEAST macro-region is increasing, the percentage of GDP is still low compared to the EU average. In real terms, the Business Expenditures on Research and Development (BERD) increased from PPS 5.7 billion to PPS 15.4 billion euro (at constant 2005 prices) between 2010 and 2019, by a compound annual growth rate of 11.8%, compared with the EU average of 3.7%. Among the BIOEAST countries, the fastest real growth of the BERD was recorded in Poland (average annual growth 21.9%), followed by Lithuania (11.3%), Bulgaria (10.6%), Slovakia and Romania (both 9.3%). The slowest growth of the BERD was recorded in Slovenia (2.9%), while business R&D spending remained almost unchanged in Latvia.

In the BIOEAST macro-region at an average of 0.8% of GDP in 2019, the BERD was significantly below that of the EU average of 1.2%. On the other hand, the BIOEAST's BERD intensity lag from the EU average decreased from -0.8 to -0.7 percentage points over the decade (2010-2019), due to much faster growth of business R&D expenditure in the macro-region than in the whole of the EU.

BERD intensity ranged from 0.1% in agriculture, forestry and fisheries to 12% in manufacture of pharmaceuticals in 2018. In the last decade, the BERD in the bioeconomy of the BIOEAST macro-region was mainly driven by the contribution of business enterprises from the pharmaceutical and chemical industries, while the contribution of plastics and food producers was significantly lower. Meanwhile, the BERD intensity was low in other bioeconomy industries. In addition, both BERD spending and its ratio to the value added decreased in agriculture, forestry and fishing over the same period.

The pharmaceutical industry (both bio-based and non-bio-based) was leading in terms of BERD spending, which amounted to approximately PPS 876 million euro and accounted for 6% of the overall BERD in the BIOEAST macro-region in 2018. In the last decade (2010-2018), business enterprise expenditure on pharmaceutical R&D increased by an average of 3.2% per year in real terms. More than 80% of pharmaceutical R&D spending came from three BIOEAST countries: Hungary (37%), Slovenia (23%) and Poland (21%), followed by Czechia (7.6%) and Croatia (6.5%).

The BERD intensity in the manufacture of chemicals and plastics (2.4% and 0.9%, respectively) was several times lower than that in the manufacture of pharmaceuticals. The business R&D

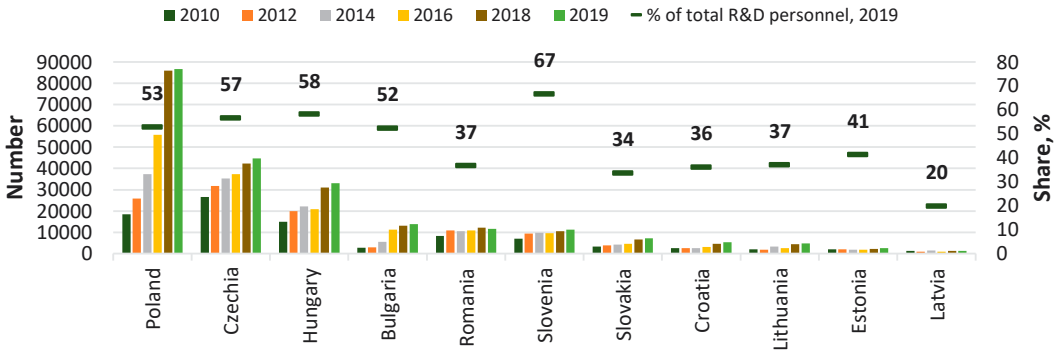
spending in both industries amounted altogether to approximately PPS 517 million euro in 2018, which accounted for 3.6% of the overall BERD in the BIOEAST macro-region. During the 2010-2018 period, business enterprise expenditure on R&D increased by an average of 3.2% per year in real terms. More than 60% of BERD spending in the manufacture of chemicals came from Poland, followed by Czechia (18.4%). In manufacture of plastics, Poland (44.7%), Czechia (21.7%) and Slovenia (13.7%) are significant contributors to the BERD.

It can be concluded that 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 BERD amounts, these account 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 GERD is observed in Latvia and Lithuania, and it is significantly lower than the EU average. The Baltic countries and Croatia are the least research-intensive countries, as the public sector – higher education and government – tends to spend more on R&D than the private sector.

R&D PERSONNEL AND RESEARCHERS

In 2019, 436,200 full-time equivalent workers were employed as R&D personnel and researchers in the BIOEAST macro-region (15% of the total in the EU). Their number has grown in recent years, rising from 273,500 in 2010. In 2019, there were 222,400 R&D personnel and researchers working within the BIOEAST macro-region's business enterprise sector (51% of the total).

Figure 14: **R&D personnel in the business enterprise sector, full time equivalent and % of total R&D personnel in the BIOEAST countries in 2019**



Source: EUROSTAT, 2022c.

BIOECONOMY RELATED RESEARCH AND INNOVATION UNDER THE HORIZON 2020 PROGRAMME

There are several Horizon 2020 programmes that are fully (such as Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy as well as Biotechnology) or partly (Climate action, environment, resource efficiency and raw materials as well as Secure, clean and efficient energy) related to the bioeconomy. In the BIOEAST macro-region, a net EU contribution under Horizon 2020 amounted to EUR 2 958.5 million (5.2% of the EU total in 2014-2020). H2020 funds intensity per capita was more than three times lower in the BIOEAST macro-region than in the EU total (EUR 29 vs EUR 110 per capita) during the same period. In contrast, the highest net EU contribution per capita was in Estonia and Slovenia, while the rest of the BIOEAST countries were far behind (Bulgaria, Poland and Romania were at the end of the rank). In comparison with the EU total, 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' (7.4% vs 5%). Among the BIOEAST countries, the highest SC2 share was reported in Slovakia (21.5%), followed by Romania (13.5%), Latvia (9%), Hungary (8.3%), Estonia and Croatia (9% each), while the lowest shares were recorded in Czechia (4.2%), Poland (4.6%) and Slovenia (6%).

R&D RESULTS: PATENTS AND PUBLICATIONS

In general, the intensity of patenting activity was much lower in the BIOEAST macro-region than in the whole EU with differences ranging from 8 to 27 times in applications per million inhabitants. Compared with the EU, the BIOEAST countries were focused more on research and technologies development in the following fields only: 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 was focused more on biochemistry, genetic and molecular biology. The citable scientific publication intensity (measured per Mio. inhabitants) was higher in the EU than in the BIOEAST macro-region in all areas, except for veterinary science.

BIOECONOMY RELATED RESEARCH AND INNOVATION STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

Table 4 and Table 5 summarise the key SWOT factors related to bioeconomy research and innovations in the BIOEAST macro-region, based on the results of an analysis of SWOT factors in national countries performed by national experts and stakeholders during the BIOEASTsUP CSA project (Task 4.2 Establishment of an evidence base for the SRIA).

Table 4: **BIOEAST macro-region strengths, weaknesses, opportunities and threats related to bioeconomy research and innovations**

SWOT: Strengths	• Bioeconomy related study programmes. • Total expenditure on RDI increases. • Available RDI personnel in the bioeconomy industries. • Highly qualified researchers in several areas of the bioeconomy. • Existence of well-known international-level research teams in several areas with immediate application potential. • Growing research activity in innovative food products and beverages, paper and pulp production, pharmaceuticals, bio-based chemicals, plastic and other areas. • Good RDI infrastructure in selected areas of the bioeconomy. • Growing cooperation in bioeconomy-related areas among the CEE countries. • Involvement in projects under the EU RDI framework programmes. • RDI cooperation between entrepreneurs and research institutions. • Growing small and medium-sized enterprise participation in Horizon 2020, EU networks and bioeconomy-related RDI.	**SWOT: Weaknesses**	• Predominantly small enterprises in the bioeconomy • Specialisation in low technology bioeconomy industries (i.e., food products, agriculture, forestry, wood and furniture, paper). • Low business activity in RDI. • Lack of qualified researchers in research institutions and business organisations. • Low attractiveness of research careers to domestic and abroad talents. • Lack of experience and participation in Joint Programming Initiatives, alliances, technological platforms, Horizon 2020, projects. • Insufficient cooperation between: a. research institutions, the business sector and policy makers in the bioeconomy industries, especially in the field of commercialisation of RDI results; b. ministries; c. researchers working in different sectors; d. researchers from the countries of the macro-region and foreign researchers; e. RDI funders (funding fragmentation); f. value chain actors. • Dependence on the availability of foreign (mainly EU) funding due to the lack of financing from the government and the private sector for RDI. • Poor correlation of public research with the needs of the private sector, giving priority to fundamental sciences over applied ones. • Insufficient skills and abilities in the commercialisation of created knowledge. • Lack of infrastructure for the development and scale-up of technologies in the bio-based industrial sector (pilot plants; open pilot facilities etc.). • Inability of the science field to adapt to the rapidly changing requirements.
SWOT: Opportunities	• Challenges related to globalisation, climate change, biodiversity and ecosystem services, food and energy security creates demand for strengthening the circular bioeconomy. • Growth in demand (private & public) for bio-based products and technologies. • New possibilities provided by the EU and national strategies and policies as well as the European Green Deal on the bioeconomy, the circular economy, renewable energy, on plastics, environmental sustainability, social cohesion. • Opportunities provided by the ERA to enhance research excellence, international collaboration, openness and inclusiveness. • Horizon Europe, the European Structural and Investment Funds as well as the European Agricultural Fund for Rural Development and European Research Council grants. • Tax incentives, InnoVouchers etc. for promotion of investments in RDI and technological renewal.	**SWOT: Threats**	• The inadequate governance of RDI, a lack of a systematic and continuous assessment of possible scenarios for future development and research agendas. • General awareness about the bioeconomy is low, and there is no integrated bioeconomy policy document. • Slow and long process to get to the results of RDI. • Uncertain market demand, increasingly high market requirements in terms of volume and continuity. • Limited national budget for R • DI and increasing the importance of international cooperation even more. • Low recognition of universities and research institutions in the international arena. • Failure to increase the level of internationalisation of research and participation in research consortia. • Insufficient generational change of scientific personnel and outflow of talented individuals to global development centres. • Insufficient stakeholder motivation and a lack of lifelong learning culture. • Weak public awareness and effect on government decisions in the field of bioeconomy.

Source: BIOEAST, 2021a.

3 CHALLENGES AND CORE THEMES

3.1. Challenges for a circular bioeconomy

Salvador et al.[17] have identified several **challenges** (*forces that make the implementation of circular bioeconomy practices more difficult, making businesses spend more resources/effort in overcoming them*) **for a circular bioeconomy** in Europe. They are, as follows:

- **lack of adequate technology** – there is a technology that already allows for taking better advantage of available bio-resources and bio-waste; however, it seems that overall, the technology might be immature as of yet, and there is much more to be done in both the short and long term for the bioeconomy to gain greater momentum. There is a need for adequate and economically feasible technologies;
- **need for investment to integrate biorefineries** – often, considerable investments are needed to integrate biorefineries and establish partnerships that would allow for cleaner and higher value paths;
- **maintaining uniform products** – one of the risks of valorising bioresources lies in their supply, which usually depends on the by-products or waste from other processes or industries. It is difficult to ensure a continuous flow or even the same mix and quality of bioresources, which might make it difficult to maintain product uniformity;
- **guaranteeing sustainability and security of biomass supply in the long term** – relying on by-products or waste from other processes or industries might pose a threat to a continuous flow and sustainable procurement of certain resources or materials. Securing continuous and sustainable supply of bioresources, great involvement, engagement and proximity of biomass suppliers and/or other industries is needed;
- **collaboration** – for valorising biomass, there is an increased need for cross-sector, private-private and public-private collaboration, e.g., for reaching new markets, joint investments, economies of scale and knowledge exchange;
- **price competitiveness** – it is difficult to compete in markets with cheaper products based on fossil resources, especially fuels;
- **motivating production of low-priced products** – in a cascaded system, if one alternative use, even though lower in the value chain, seems achievable, it can avoid the production of an alternative product that is higher in the value chain but seems costlier;
- **quality or efficiency of final products** derived from bioresources might be perceived as lower than those of fossil/non-renewable resources, which can be the case of fuels. This might pose a challenge for society to switch to bio-based products altogether;
- **lack of knowledge/skills/competencies** – some industries are still very traditional, with a linear mindset, and there is a 'need to change the mentality of the industry'. Companies might be reluctant to go into new business areas for valorisation of waste because use or recovery of the resource/material is outside the company's core business. Moreover, and therefore, they might lack specific knowledge, skills or competency to manage related operations;

17 Salvador, R., Barros, M.V., Donner, M., Brito, P., Halog, A., De Francisco, A.C. 2022. How to advance regional circular bioeconomy systems? Identifying barriers, challenges, drivers, and opportunities. Sustainable Production and Consumption. Volume 32, Pages 248-269, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2022.04.025

- **lack of public/consumer awareness** – in the market, lack of awareness is present both on the consumer and the producer side. From the market side, buyers (B2B and B2C) might not be willing to try out new products. From the supply chain side, there might be a lack of collaboration for solving problems, and difficulties in finding right partners, getting them onboard and working together;
- **finding/unveiling market demand for bio-based products** might sometimes require the creation of new market segments;
- **lack of incentives for upcycling** – there is a lack of specific incentives/policies promoting and sustaining the use of a resource, and economic incentives or opportunities, or support for pursuing more value-added alternatives instead of cascading down;
- **lack of regulations and policies to promote environmentally sound product design** – there appears to be little to no specific regulations or policies seeking to promote environmentally sound product design via bioeconomy;
- **company size** – on the one hand, large companies are not necessarily resistant to change, but they lack the required dynamic capability; they lack knowledge, most of the time, of the end user of their products, making their strategy definition difficult. Small companies, on the other hand, consider themselves too small to take on the complications and costs of pursuing new paths;
- **scaling-up** – many bioeconomy products still lack sufficient value generation and thus large-scale commercialisation, hence being only prototypes.

Challenges related to COVID-19 and the war in Ukraine also call for **restructuring supply chains** (e.g., extraction/collection and transportation of resources) due to economic fallout[18].

According to Ronzon et al.[19] and Piotrowski& Dammer [20], the BIOEAST macro-region also faces the following challenges:

- **a productivity gap in agriculture**,
- **untapped potential of agricultural and forestry residues** for further generation of higher value-added biomass application,
- **lack of biorefineries** (except for some sugar-/starch-based cluster biorefineries),
- the macroeconomic significance of the bioeconomy – a significantly stronger representation of agriculture, particularly in employment,
- comparably high employment multipliers (for each million euro invested in the national bioeconomy sector, up to 55 jobs could be created in these countries, mainly driven by primary agriculture).

The national experts from the BIOEAST countries also stressed the **climatic and ecological challenges** (impacts of climate change, desertification, appearance of new diseases and pests, biodiversity loss etc.) and the **weakness of the education system** in the BIOEAST countries.The BIOEAST initiative could also contribute to solving the challenges identified by mobilising research resources and expanding cooperation between the stakeholders. Under the BIOEAST initiative, joint research activities based on the strengths of and opportunities for the BIOEAST macro-region (Table 4 and Table 5) will allow for more efficient use of research experience and limited human resources, as well as avoid research duplication and prevent fragmentation in the field of RDI.

18 Salvador, R., Barros, M.V., Donner, M., Brito, P., Halog, A., De Francisco, A.C. 2022. How to advance regional circular bioeconomy systems? Identifying barriers, challenges, drivers, and opportunities. Sustainable Production and Consumption. Volume 32, Pages 248-269, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2022.04.025

19 Ronzon T, Piotrowski S, Tamosiunas S, Dammer L, Carus M, M'barek R. 2020. Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU. Sustainability. 12 (11, 4507):1-13. doi.org/10.3390/su12114507

20 Piotrowski S. & Dammer L. 2018. State of play of Central and Eastern Europe's bioeconomies. SCAR Bioeconomy Strategic Working Group and CASA (Common agricultural and wider bioeconomy research agenda). Available at: https://scar-europe.org/images/SCAR-Documents/Reports_outcomes_studies/BSW2_18-11-22_State-of-play-of-central-and-eastern-Europes-bioeconomies.pdf

However, a strength of the BIOEAST macro-region – good RDI infrastructure in selected areas of the bioeconomy – in combination with the joint research activities will allow for more efficient sharing of the limited research infrastructure and development of new opportunities (by enhancing the current technological solutions and developing new techniques). The joint research activities of the BIOEAST initiative will also facilitate the participation of research groups from the macro-region in international research projects and promote the attraction of additional funding, thereby reducing the problem of insufficient funding for RDI in the macro-region.

The nature and scope of challenges in the bioeconomy, as well as the macro-region's weakness – insufficient cooperation – necessitates the expanding of cooperation, not only between researchers working in different sectors but also between stakeholders, as well as international cooperation. Expanding cooperation is going to contribute to reaching new markets, joint investments, economies of scale, knowledge sharing[21] and ensure other benefits. Sharing knowledge and experience will help to develop and implement BIOEAST national and regional policies on the bioeconomy, which could be a catalyst for attracting investments to the BIOEAST macro-region. The joint research activities of the BIOEAST initiative, knowledge and experience sharing as well as cooperation expansion will also reduce the BIOEAST macro-region's weaknesses identified previously and minimise the impacts of the threats (Table 4 and Table 5).

The BIOEAST SRIA has been designed to deal with **challenges to the bioeconomy**, eliminate the **weaknesses** of the BIOEAST macro-region and minimise the impact of the **threats**, consolidate the knowledge base, mobilise research and innovation, as well as expand cooperation and integration. The BIOEAST countries have identified seven BIOEAST Core Themes (each BIOEAST TWG is assigned a Core Theme):

1. Agroecology and Sustainable Yields
2. Forestry Value Chains
3. Food Systems
4. Bioenergy and New Value-added Materials
5. Advanced Biochemical and Biomaterials
6. Freshwater Based Bioeconomy
7. Bioeconomy Education

A description of the needs of each BIOEAST Core Theme has been structured into several Strategic Thematic Areas, while a description of each Strategic Thematic Area consists of 3 elements:

1. challenges in relation to the Strategic Thematic Area;
2. main research topics are listed in relation to the challenges. More detailed descriptions of the research topics are available in Thematic SRIAs;
3. an expected outcome and impact.

The descriptions of the BIOEAST core themes have been produced by BIOEAST TWGs. For more information about the Thematic Working Groups, see: https://bioeast.eu/ → Bodies → Thematic Working Groups.

21 Salvador, R., Barros, M.V., Donner, M., Brito, P., Halog, A., De Francisco, A.C. 2022. How to advance regional circular bioeconomy systems? Identifying barriers, challenges, drivers, and opportunities. Sustainable Production and Consumption. Volume 32, Pages 248-269, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2022.04.025

3.2. Core themes

CORE THEME 1: AGROECOLOGY AND SUSTAINABLE YIELDS

Strategic Thematic Areas:

TA1: Soil management
TA2: Transition to pesticide-free agriculture
TA3: Genetic resources and agricultural diversification
TA4: Innovation, smart agriculture, digitalisation and knowledge sharing
TA5: Animal health and welfare
TA6: Short food supply chains and rural development

TA1: SOIL MANAGEMENT

CHALLENGES:

The likelihood, frequency, duration and severity of extreme weather and soil moisture problems (e.g., droughts and inland inundation) resulting from **climate change** will increase. In future, the quantitative and temporal distribution of precipitation will become more extreme. Soil is sensitive to environmental and anthropogenic stress and degradation processes, which endangers sustainable biomass production. **Soil degradation** in agricultural land is **caused by erosion and inappropriate land management** as well as physical, chemical and biological degradation. The extent of **contaminated, non-agricultural and sealed soil** is also increasing. Although BIOEAST countries are both **socially and economically diverse**, they generally lag technologically (due to capital shortage). Their land and ownership structures are fragmented, cooperation is lacking, there is a high number of consumers on low incomes, there is only a low degree of cooperation among farmers, adaptation and knowledge transfer are slow, people have been alienated from the land and the environment, and there is a general lack of knowledge about soils. Farmers are not sufficiently familiar with soil-friendly cultivation methods or sustainable farming and precision technologies nor do they often strive for quality and long-term sustainability. The **soil monitoring systems** are present and functioning at very different levels in different BIOEAST countries.

MAIN RESEARCH TOPICS:

RT1.1: Transition to environmentally sound, low emission, soil friendly agricultural technologies

RT1.2: Restoring deteriorated water-holding capacity due to soil degradation through appropriate land use and agrotechnical methods

RT1.3: Biological processes occurring in the soil due to farming and in relation to climate change; research related to the rhizosphere

RT1.4: Improving the carbon retention/carbon sequestration capacity of soils and capacity of related projections

RT1.5: Development of methods for sustainable organic matter management to improve soil fertility and health

RT1.6: Establishment of scientific bases for soil advisory systems, aiming of soil conservation management and sustainable land-use focused on erosion control

RT1.7: Reduction of inputs of organic and inorganic materials in agri-, horti- and viticultural systems

RT1.8: Developing technologies based on by-products and side streams in relation to soil loading

RT1.9: Social perception of soils

RT1.10: The long-term impact of irrigation on soils

RT1.11: Remediation and recultivation of damaged areas

RT1.12: Identification of soil genetic processes, properties that indicate the soil improvement or degradation trends, and design of respective monitoring approaches

EXPECTED OUTCOME AND IMPACT

Execution of the outlined research topics will contribute to proper management of soil moisture and the mitigation of excess water or lack of water in soil. The outcomes also include a better understanding and management of soil organic matter content and its role in carbon sequestration and in the reduction of soil-released GHG in the atmosphere. The research topics will contribute to sustainable circular bioeconomy and the reduction of agricultural environmental pressures. More specifically, reduced soil sealing, and increased recultivation are expected that allow for the utilisation of degraded, damaged and contaminated land for biomass production. The research on monitoring approaches will contribute to improved evidence-based policy making.

TA2: TRANSITION TO PESTICIDE-FREE AGRICULTURE

CHALLENGES:

Natural assets and biodiversity are declining and disappearing at a rapid rate because ecosystem services are not considered an integral part of production in the current (agricultural/economic) system. **The current linear farming models do not reward sustainability sufficiently**, and few farmers are encouraged to engage in chemical pesticide-free farming. Policies aiming to withdraw pesticides without alternative measures for disease, pest and weed control fuels resistance among stakeholders. Therefore, prohibition of chemical pesticides should be coupled with making available new solutions. Current practice where for the most part **sustainable food** (e.g., organic food) **comes with a heftier price tag, and an increasingly large sector of society cannot afford it** must be changed. There is a lack of consumer education about the qualities of pesticide-free products. There is a general **lack of a multidisciplinary and multi-actor approaches and knowledge transfer in aspects of plant cultivation** between scientists, advisors, and famers on the alternative/new methods of crop protection. The proportion of **organic farming is well below 10% in the BIOEAST countries.** Having new biological or organic plant protection products approved and marketed is costly and, therefore, beyond the reach of small companies. In the BIOEAST region, there are significant differences in land concentration and the size of holdings that can be operated economically, and **the livelihood of small farms and maintaining the living standards in the countryside are major challenges**. Climate change, changes in land use and global trade are all amplifying the **emergence of new diseases, pests and the invasion of alien species.** There is a lack of knowledge on changing communities of microorganisms and invertebrates in the context of changing environment (climate, plant communities, cultivation technologies) and the impact of these changes on agricultural crop cultivation and the production of food raw materials.

MAIN RESEARCH TOPICS:

RT2.1: Participatory technology development via the establishment of a Living Lab and Light Houses network for implementing agro-ecological transition and chemical pesticide-free agriculture

RT2.2: Measurement of the ecosystem services of farming and monitoring of changes linked to farming practices

RT2.3: Development of a policy framework for sustainable transition to agro-ecology

RT2.4: Adaptation to climate change – monitoring and forecasting of old and new pests, and invasive species

RT2.5: Creation of a biological basis for chemical pesticide-free agriculture; plant breeding for increase tolerance and resistance to biotic and abiotic stress

RT2.6: Traditional farming methods in the BIOEAST region

RT2.7: Digitisation in plant protection to prevent the use of chemical pesticides and reduce the current level of their application

EXPECTED OUTCOME AND IMPACT

The research topics outlined above will lead to a more widespread multidisciplinary and multi-actor approach in plant cultivation with less chemical pesticides in the BIOEAST region. The research will improve our understanding of the impacts of farming methods on ecosystem-services, and thereby will contribute to the widespread use of proper agro-technical practices. In addition, the widespread use of IT and digital tools among agricultural producers in the BIOEAST region will be achieved, thereby contributing to the digitalisation of EU agriculture.

TA3: GENETIC RESOURCES AND THEIR DIVERSIFICATION IN AGRICULTURE

CHALLENGES:

Continuous loss of biodiversity (gene erosion), and concentration and the narrowing of available varieties in agricultural input markets. **Climate change** will prolong dry periods and increase the number of days with temperatures above 35°C, thereby **increasing the unpredictability of farming** in the region. Climate change is setting the scene for the **appearance of unknown pests, pathogens and invasive alien weeds**, which threaten both farming and farmers' livelihoods. **Current farming technologies** and the focus on short-term **profitability expectations will make farming much more difficult** in the near future, which will also hinder seed and commodity production. **Farmers lack information,** use adverse farming habits and largely **focus on short-term**, **immediate profits**. Farmers lack **basic expertise in the agro-technological knowledge of sustainable farming methods, suitable varieties and alternative species**.

There is a significant number of currently **underutilised genetic resources** stored in gene banks, which, if involved in selection and farming, could produce varieties (and seeds) that adapt better to the effects of climate change. Several national Biodiversity and Gene Conservation Centres in the BIOEAST region store thousands of gene bank accessions; however, the information about them is scarce. **The regional organic seed market is under-developed** with a limited offer, insignificant organic plant breeding and low demand for organic seed. **There is a prevalence of the monodisciplinary approach** in plant breeding, gene conservation and a strong 'top-down' approach among breeders **as well as insufficient public involvement** in the conservation and use of genetic diversity.

MAIN RESEARCH TOPICS:

RT3.1: Climate-adaptive agro-technologies and plant and animal breeding

RT3.2: Interdisciplinary and multi-stakeholder participatory plant breeding practices

RT3.3: Upscaling the organic seed sector in the BIOEAST region

RT3.4: Exploring the potential of genetically more diverse agriculture

EXPECTED OUTCOME AND IMPACT

The research topics outlined above will contribute to the adoption of improved and more sustainable gene conservation practices in the BIOEAST region. It is expected that the adoption of plant cultivars (i.e., varieties and populations) adapted to the effects of climate change will increase the adaptive capacity of farmers and will result in an increase and spread of genetic diversity. The spread of more sustainable production systems in the region promotes the transition to agro-ecological farming practices. The development of diversified cultivation methods and crop combinations will reduce the risk posed by climate change and can generate more stable income for farmers.

TA4: INNOVATION, SMART AGRICULTURE, DIGITALISATION AND KNOWLEDGE SHARING

CHALLENGES:

Most farmers are still reluctant to embrace new technologies, and their participation in the transfer of up-to-date knowledge is still limited. The innovation ecosystem in agriculture needs to be developed, and coordination between the different types of actors taking part in the innovation process and different support programmes needs to be strengthened. **There is an insufficient usage of tools that would improve the environment or reduce the already negative impacts and emissions of agricultural production**. The link between basic and applied research which fundamentally determines the quality of multidisciplinary RDI is still tenuous. The lack of a concentrated RDI infrastructure, an outdated non-profit research network and ageing instrument infrastructure, **inertia, low productivity and efficiency in the use of resources, modern technologies and innovative solutions** all hold back the development of RDI.

There is also an absence of innovation capacity through which the added value of agro/food/forestry in the primary production and production chain can be increased and fair profit sharing (from primary producer to retailer) may occur. Also, the **current structure of the agro-food sector in the region creates problems in the innovation potential of primary production since input-intensive large farms typically have higher absorption capacity for innovation than small, family farms. The fear of transparency among certain actors in the food value chain** (input traders, farmers, purchasers, processing agents, sales persons) also poses an obstacle to the introduction of monitoring systems. The **active participation of consumers in the use of information gained** from production poses difficulties, and awareness characterises only a small number of consumers.

MAIN RESEARCH TOPICS:

RT4.1: Transfer of thematic knowledge and establishment of educational knowledge bases for advisors in identified agricultural shortage areas

RT4.2: Developing new ICT solutions and sharing them with agricultural producers

RT4.3: Development of an incentive system to boost participation in agricultural data initiatives and data spaces

RT4.4: Developing innovation ecosystems through the better utilisation of the potential of innovation consultants/advisors

EXPECTED OUTCOME AND IMPACT

The promotion of innovation, smart agriculture, digitalisation and knowledge sharing through research activities will improve the flow of up-to-date information in the food systems and will enhance wider use of ICT solutions in agriculture and food supply chains. Also, more extensive digitalisation will result in broader distribution of and use of processed farm data both for needs-based and results-oriented RDI and policy development.

TA5: SUSTAINABLE ANIMAL HUSBANDRY AND ANIMAL WELFARE

CHALLENGES:

Antimicrobial resistance (AMR) is one of the most important 'One Health' challenges of our time, which affects human and animal health and environment protection. The **lack of application of novel medicinal agents** (e.g., phytotherapy) in order to minimise the impact of infections on animal health is apparent in the BIOEAST region. **Difficulties in complying with national and EU legislation**, differences in attitudes and scarcity of capital, significant even by international standards, are also likely to be an obstacle to innovation efforts. It is also a major challenge for farmers to comply with new legislation and **to meet conflicting and changing consumer needs**, especially when these external effects create development 'pressure' that affects the technologies used, and is often unprofitable and inefficient from an environmental and animal welfare point of view.

Developments like price fluctuations, increase in imported goods and fewer export opportunities may also present difficulties. There are several **agro-technical problems in the handling and processing of animal food** and the increase in GHG emissions as the result of the intensification of animal farming poses a threat. **Land shortage linked directly to livestock farming** also poses difficulties. **Numerous invasive interventions performed routinely**, close range animal husbandry failing to meet the ethological needs of animals and the lack of an animal health approach based on preventive methods also raise animal welfare issues. **The widespread use of animal species with high yields** for intensive production encourages production with an emphasis on quantity rather than high quality. Another problem is that current **EU agricultural subsidies are not sufficiently subject to quality standards**, and an increasingly acute shortage of skilled and reliable labour is a particular challenge in agriculture, especially in livestock breeding.

MAIN RESEARCH TOPICS:

RT5.1: Reduction in the use of antimicrobials using new diagnostic methods

RT5.2: Production of quality agricultural products while reducing environmental pressure

RT5.3: Facilitate technological shifts to ensure better animal welfare conditions

RT5.4: Reduction in the amount of slurry generated by close range animal husbandry and facilitating the landspreading of stable manure on arable land

RT5.5: Conservation of the genetic diversity of farm animals and the protection of biodiversity

EXPECTED OUTCOME AND IMPACT

This strategic research area will contribute to reduction in the use of antimicrobials in animal husbandry and in market pressure, and it will facilitate technological changes to ensure improved animal welfare and animal husbandry conditions. The research results will help to reduce the amount of slurry generated by close range animal husbandry, and facilitate the application of manure on arable land. Conservation of biodiversity will be promoted as well as sustainable animal farming practices and the protection of genetic diversity among farm animals. It is expected that new diagnostic methods are developed and upscaled.

TA6: RURAL DEVELOPMENT

CHALLENGES:

Some of the **impacts of climate change** – mainly desertification, shrinking surface and groundwater resources, increasingly lengthy dry periods, changes in the structure and species composition of forests – affect the BIOEAST region more profoundly. Currently, there is a l**ack of adaptation strategies to these emergent threats** (pests, diseases, invasive non-indigenous species, increase in mycotoxin infections). There is a **lack of modelling, data collection and impact assessments** in the area of local food supply chains and rural development, which could potentially support long-term local and national decision-making. The role of **wildlife management** and hunting in the region is greater and more important than in Western Europe; however, it is underrepresented in EU programmes, as it is often excluded from strategic planning. In rural regions**, sufficient technological funding and access to related information is limited**, which also hinders rural competitiveness and modernisation, and restricts livelihoods in rural areas. Furthermore, **ecosystem-based, long-term planning (at local and national levels) in decision-making is also lacking**, as is better coordination between policies and regulation.

A **widening technological gap between large-scale and small-scale farming** is a crucial issue in the region. **Small local producers face disadvantages in attracting financial resources and access to retail chains.** The **continuous decline in the agricultural workforce** has been a problem for decades, as has the increase in rural migration, resulting in the depopulation of the countryside. **Consumer awareness** is particularly **weak in terms of the quality, price, origin and sustainability parameters of food production.** Farmers who create additional benefits (incl. lower emissions, better habitat quality, less harmful water run-offs) do not have price advantages in comparison to less environmentally friendly producers. **The transfer and dissemination** of new knowledge and the results of research and development to farmers **are not efficient enough.**

MAIN RESEARCH TOPICS:

RT6.1: Furthering the sustainability of small-scale and family farms and other rural businesses

RT6.2: Dissemination of good practices for sustainable agro-community adaptation to climate change

RT6.3: Development of data-based decision support systems for climate adaptation in rural areas for policy makers and governmental bodies

RT6.4: Placing wildlife management on a new footing

RT6.5: Development of circular business models to strengthen local food supply chains

EXPECTED OUTCOME AND IMPACT

The outlined research will lead to diversified rural production and increased self-sufficiency at local levels, stronger rural and local communities, and the increased prestige of rural life. Also, changes in approaches to wildlife management are expected, and new business solutions will be identified and business models created that meet the needs of stakeholders in local food supply chains.

CORE THEME 2: FORESTRY VALUE CHAINS

Strategic Thematic Areas:

TA1: Forest resources in changing conditions
TA2: Sustainable wood production chains
TA3: Keeping and further strengthening of traditional and development of high-tech wood processing industries
TA4: Paper-pulp technologies
TA5: Recycling and cascading system of wood and wood products use
TA6: Forest ecosystem services and regional development
TA7: Education and communication

TA1: FOREST RESOURCES IN CHANGING CONDITIONS

CHALLENGES

Forest resources are under pressure due to climate change and a changing societal demand, which result in the changes of goods and services demanded from forest ecosystems. The severe impacts of climate change have led to the need to strengthen the capacity of forests to adapt to new conditions, including the change of tree species composition. There is a need to improve the capacity of forests to tolerate ongoing climate change through purposefully differentiated forest management leading to conservation and enhancement of the biological diversity of forest ecosystems ensuring adequate timber production and other forest functions.

MAIN RESEARCH TOPICS:

RT1.1: Ecosystem dynamics inventory, monitoring, modelling and risk management

RT1.2: Silvicultural systems supporting wood production

EXPECTED OUTCOME AND IMPACT

This strategic research area will contribute to development and implementation of methods for effective forest inventory and monitoring, employing technological advances in remote sensing and field electronic tools for data collection. Forest modelling and decision support systems will be developed for climate change adaptation to support sustainable forest management in changing conditions, including in small-scale forests.

Incentive schemes for climate change mitigation through carbon storage and water management in forests will be developed. New knowledge will be created on the role of environmental chemistry in forest soil management regarding soil sustainability, nutrient balance, and assessment of chemical stresses. Monitoring and mapping systems, and advisory services will be developed for forest protection and risk management, including pest identification. The possibilities for extending wood production through the management of trees outside forests, implementing agroforestry systems and restoring forests at degraded forest land will be assessed. Pathways will be identified for increasing the value production of broadleaved forests using management systems that support the production of special, high-quality types. Cropping systems will be developed for fast growing tree species, and high-yield silvicultural systems. Breeding and testing of perspective native and introduced tree species aimed at higher quantity, better quality and stability of forest production, including conversion of unstable coniferous forests.

TA2: SUSTAINABLE WOOD PRODUCTION CHAINS

CHALLENGES

In sustainable wood production chains, we should introduce new technologies and set-up an updated information technology support. Smart logistics is a crucial part of efficient supply chains and is closely connected with supply chain management and further smart manufacturing. Digital transformation is a foundation for the further development of efficient forestry production chain that can support industries and secure the supply of wood. Security of supply of wood to traditional, and new emerging industries and for the bioenergy sector is a key for the development of a stable bioeconomy sector. Moreover, the increased amounts of felling due to the negative effects of climate change result in the fall in prices of wood and increase of offer of wood types. To maintain the wood market, stable development of international or regional platforms for the exchange of information are needed. It is necessary to focus on the production of wooden products with higher added value in order to secure revenues for foresters and ensure the continuation of sustainable forest management.

MAIN RESEARCH TOPICS:

RT2.1: Sustainable wood market potentials and security of wood supply

RT2.2: Planning of forest operations and harvesting infrastructure

RT2.3: Forest economy & supply chain management

RT2.4: New business models for private forest owners

RT2.5: Digital transformation and smart logistics

RT2.6: Development of regional/international market for round wood

EXPECTED OUTCOME AND IMPACT

The outlined research will lead to forest road network planning and mapping using Lidar and Radar sensors, and improvement of the processes in timber harvesting and processing according to the quality properties of timber. Market potentials for planning of new investments in wood industry will be assessed. New models will be developed for the economic evaluation of management measures from forest establishment to final harvest. New solutions will be found for forest policy and governance to address constraints and balance wood production and other demands. Decision support and prediction tools will be built on integrated knowledge base to support forest management. A quality assessment system for forest contractors will be created to assure the quality and recording of forest operations. Network of forest professionals, advisors, owners, contractors, policy makers and researchers will be further strengthened. New markets and new business opportunities for forest owners will be mapped that encompass also socio-economic models of forest management. This will lead to increase in more efficient marketing of wood and forest services, as well as new innovative pathways for efficient operations in private forests. Innovation needs for the labour market and forest entrepreneurs and good practice examples will be mapped, as well as for integration of women into working places and decision-making processes in the forest sector. Opportunities for digital transformation, smart logistics, online timber trading, marketing, procurement and auction will be assessed.

TA3: KEEPING AND FURTHER STRENGTHENING OF TRADITIONAL AND DEVELOPMENT OF HIGH-TECH WOOD PROCESSING INDUSTRIES

CHALLENGES

Create the conditions to support the increase in the competitiveness and viability of the whole value chain based on forestry and domestic processing and the use of wood. Fill the gaps in the technologies and products of non-coniferous wood processing, use of small diameter wood, developing new products and new markets.

MAIN RESEARCH TOPICS:

RT3.1: Development of high-tech technologies and increase in the processing of non-coniferous logs

RT3.2: Development of regional and international market for primary wood products

RT3.3: Organisation of international (for CEE region) network of wood processing industry and other connected stakeholder

EXPECTED OUTCOME AND IMPACT

It is expected that the outlined research will lead to new hardwood products, detection of wood defects by 3D log scanning, optimising of wood types and sawing, wood flow tracking, data connectivity and transfer using internet of things in order to increase the added value of production, laser cutting of logs and wood, development of web-based platform to connect local and national markets of primary wood products. This research supports substitution of non-renewable materials with wood in the building sector, and standardisation of processes for better recyclability of wood products.

TA4: PAPER-PULP TECHNOLOGIES

CHALLENGES

Although the life span of paper is short and processing inputs are high, paper is produced from a renewable resource, and paper packaging and other products are recyclable and biodegradable, from an environmental perspective.

MAIN RESEARCH TOPICS:

RT4.1: Special paper production and testing

RT4.2: Functional fibres formation and paper surface treatment development

EXPECTED OUTCOME AND IMPACT

The activities of this strategic thematic area will lead to development, testing and production of special papers, e.g., inorganic fibres, layered special papers, polymer reinforced paper, high precision paper. Non-destructive testing methods will be developed, e.g., based on spectroscopy. Paper surface treatment research will lead to better understanding about paper transmission parameters, structure and the anisotropy of the paper, and properties of the fibres and the fibre network. Paper surface treatment technology will be developed for smart packaging solutions, including antimicrobial, antibacterial and anticorrosion papers, barrier papers, active hygienic papers, mechanic-active papers and boards.

TA5: RECYCLING AND CASCADING SYSTEM OF WOOD AND WOOD PRODUCTS USE

CHALLENGE

The cascading use of wood represents an efficient use of this renewable natural resource in the circular economy. The challenge is to use timber efficiently, preferring products of higher added value, longer lifespan, facilitating cascading use of wood and integrating energy production, while considering renewable energy goals as well as carbon emissions reduction goals.

MAIN RESEARCH TOPICS:

RT5.1: Cascading use of wood in mechanical processing

RT5.2: Increase the recycling of wood products

RT5.3: Empower the position of all actors (including private forest owners, farmers and consumers) in the innovative value chains

RT5.4: Advanced technologies for wood biomass decomposition

RT5.5: Implementation of quality standards for wood fuels

RT5.6: Efficiency of energy production from wood

EXPECTED OUTCOME AND IMPACT

Expected outcomes include optimised models of technological chains of cascading use of wood for construction materials, furniture industry, pulp and paper industry, agglomerated materials, chemical industry (wood polymers, carbon fibres, composites, nanotechnologies), and biofuels. Variant chains of the technological procedures of cascade processing for optimised wood utilisation will be developed. Functionally and inter-operable prefabricated building construction assembly and disassembly systems will be developed that include tools supporting reuse schemes. Wood waste thermo-chemical recycling technology will be developed that includes decomposition and separating methods in a continuous process. Analytical methods for chemical contamination and impurity determination in waste wood and use of spectroscopy in wood waste recycling technologies will be developed. Factors affecting energy wood production from private forests and short-rotation woody plantations will be assessed. Impacts of ecolabels (certification and product origin) on consumer choices will be determined. The outlined research will lead to enhanced value chain networks and high quality of non-food forest products and agroforestry products. The research supports setting up wood-energy chain – the production of energy wood in forestry, non-forest land and the in the wood processing industry and waste management: dimensional adjustment, high-efficiency combined heat and energy production, wood gasification and liquid fuel production. Wood ash utilisation opportunities in the construction, production of building materials, and fertilisers will be established, as well as for liquid wood-based waste utilisation. New business models and partnerships for smart energy grids based on woody biomass will be developed. The research will lead also to high-quality wood-based fuels and modern boilers for households and central heating systems.

TA6: FOREST ECOSYSTEM SERVICES AND REGIONAL DEVELOPMENT

CHALLENGES

Aside from the production of wood and non-woody products, forests also provide ecosystem services for which payments may be considered, and contribute to the resources available for forest management. For example, in Croatia, low-productivity forests in karst areas with a high risk of fire cover almost 40% of the total forest land. In such forests, the greatest value is in the forest ecosystem services they provide. Payments for the ecosystem services (PES) will be even more important in the future, due to climate change and the new challenges that forest ecosystems are facing. The level of public awareness of the results of works and projects financed with PES should be increased. Considering the trends of rural abandonment, the role of the forest sector in bioeconomy is also to support economic growth in rural areas and contribute to the economic growth of the macro-region. The connection of local actors is limited; a network of local consultation centres would support the entrepreneurship of local micro-, small- and medium-sized enterprises and strengthen access to activities related to forest management and social enterprises.

MAIN RESEARCH TOPICS:

RT6.1: Tools to support the marketing of forest services

RT6.2: New green tourism products connecting CEE region (hiking trails, etc.)

RT6.3: Development of the local market for non-wood products from forests

RT6.4: Identification of priorities in forest ecosystem services (FES)

RT6.5: Setting national schemes for supporting forest ecosystem services

RT6.6: Stimulation of interlinks within sustainable bioeconomy

RT6.7: Support the network of local consultation centres and job creation in the regions

EXPECTED OUTCOME AND IMPACT

Assessment tools will be developed for country specific priorities in FES together with tools to support specific forest management and the marketing of forest services. Local markets for FES and non-wood products from forests will be strengthened. Legislative environment will be adjusted for the implementation of publicly and privately supported schemes for FES. New value chains will be developed and value-added jobs created to sustain a viable rural society. Agroforestry systems will be developed as well as models of short rotation woody crops that consider environmental, economic, and social implications. Territorial (local and regional) bioeconomy systems will be enhanced to support regional development and sustainability.

TA7: EDUCATION AND COMMUNICATION

CHALLENGES

Increase the efficiency of forestry research and innovation in the care of forest ecosystems by creating national priorities for science, research and innovation, focusing primarily on the impacts of climate change on forest ecosystems in the landscape, modern technologies and other areas under research in Europe. Adapting the content of all levels of education (including lifelong learning) to the changing requirements of forestry practice and research so that graduates can respond to them in a timely and effective manner. Raise the awareness of (small) forest owners about the risks associated with climate change. In addition, education should also focus on the non-forest public in order to gain a deeper understanding of the importance of forests and forestry for the sustainability of society, for example through forest pedagogy. The role of forestry in the bioeconomy and its value chain approach could be part of forestry curricula.

MAIN RESEARCH TOPICS:

RT7.1: Updating of strategic research and innovation agenda of forestry research

RT7.2: Update of forest-related education curricula for secondary and university studies adapted to trends in circular bioeconomy

RT7.3: Building tools, networks and infrastructures for knowledge transfer and motivation of stakeholders towards implementation of circular wood-products and services-based circular bioeconomy

EXPECTED OUTCOME AND IMPACT

The planned research topics will lead to up-to-date research and innovation agenda for forestry research and allocation of adequate resources. Forest-related education curricula for secondary and university studies will be adapted to trends in circular bioeconomy. Tools, networks and infrastructures will be developed for knowledge transfer and motivation of stakeholders towards implementation of circular wood products and services-based circular bioeconomy.

CORE THEME 3: FOOD SYSTEMS

Strategic Thematic Areas:

TA1: Sustainable Food Production
TA2: Power and information in the food system: strengthening the food environments and vulnerable actors in the food chains
TA3: Research, innovation, technology and investments for future sus tainable food systems
TA4: Promoting sustainable food consumption and the shift to healthy, sustainable diets

TA1: SUSTAINABLE FOOD PRODUCTION

CHALLENGES:

Food production in the BIOEAST region is characterised by the traditional agricultural model based on increased use of chemical fertilisers, and relatively low level of knowledge and technology transfer to primary producers compared to other European regions. Therefore, the share of organic and less intensive farming in the agricultural production and land use systems should be increased. There is a need to ensure crop safety in the context of sustainable use and utilisation of plant protection products. In order to reduce biomass waste and losses, there is a need for new management systems for biomass collection and processing from primary producers. Currently, the limited sources for sustainable and reusable packaging (avoiding non-renewable and fossil-derived plastics) need to be overcome, while optimising the preservation of nutritional quality of primary products and ensuring food safety.

MAIN RESEARCH TOPICS:

RT 1.1: Ensuring sustainable food production by human and financial capital investments into innovation, skills and technology shift

RT 1.2: Production systems for reduced use, risk and dependency on pesticides

RT 1.3: Measures for reducing biomass loss and waste in primary production

RT 1.4: Integration of processing technologies in the agri-food supply chain to reduce food waste and find the best use of the raw materials and by-products

RT 1.5: Bring into practice state-of-the-art preservation technologies (with special emphasis on environmentally friendly packaging, storage conditions etc.) to extend the storability of raw materials and the shelf life of final products

EXPECTED OUTCOME AND IMPACT

The proposed research topics will contribute to selection of investments that enable farms of all sizes to take advantage of new technologies and information flows. A significant shift away from the use of pesticides and towards production systems that use alternative agricultural inputs will be initiated. The involvement of owners and managers of medium, large and very large farms in the conversion process is crucial for this. The limitation of losses of biomass during agricultural production as well as the increased use of biomass raw materials and residues will be achieved through optimisation of production techniques, raw material storage, transport and the creation of semi-finished products at primary producer level.

TA2: POWER AND INFORMATION IN THE FOOD SYSTEM: STRENGTHEN THE FOOD ENVIRONMENT AND VULNERABLE ACTORS IN THE FOOD CHAINS

CHALLENGES:

The BIOEAST region is lacking a systemic approach to boosting innovation and investment in short food chains and related new business models. Also, there is a strong deficit in trust and in joint action, both in horizontal and vertical collective actions. The dependence on non-renewable, unsustainable resources, whether sourced domestically or from abroad, should be reduced. One of the ways for this is through the integration of renewable energy sources and more energy efficient farming practices, agro-food systems and logistics. Innovations on digitalisation in agriculture and agri-food value chains are needed to enhance productivity, efficiency and traceability. Food environments need to be strengthened to secure the proper connection of producers and consumers, support the digitalisation of primary producers, develop a fast and easy tool for the detection of food frauds and provide information hubs in order to help personalise producers. The current lack of data on food fraud in the food supply chain needs to be overcome. The bargaining position of farmers should be strengthened and their share in creating environmental and economic added value in food supply chains should be increased.

MAIN RESEARCH TOPICS:

RT 2.1: Integrating sustainable short food chains and new green business models in food processing, wholesale, retail and food services in the food systems

RT 2.2: Cooperation of primary producers to support their position in the food chain and non-legislative initiatives to improve transparency

RT 2.3: Tackling food fraud along the food supply chain

RT 2.4: Improving the knowledge- and information base on the functioning and performance of short food chains

EXPECTED OUTCOME AND IMPACT

It is expected that the proposed research topics will result in applicable and regionally specific cooperation models for farmers, consumers and intermediaries (like food hub managers, facilitators, chefs). A deeper knowledge is provided to the actors in food chains about the techniques and methods on how to shorten food supply chains. Also, more information will be provided to consumers to ensure that the food products they purchase are healthy, nutritious and meet all the necessary requirements, and how they can be protected from frauds. Information feedback loops will be created which are expected to help producers understand consumers and help consumers build trust towards local producers. New innovative and digitised food chain models will be developed and multiplied that are beneficial for the environment and climate, as well as for the main participants, especially farmers and consumers.

TA3: RESEARCH, INNOVATION, TECHNOLOGY AND INVESTMENTS FOR FUTURE SUSTAINABLE FOOD SYSTEMS

CHALLENGES:

While the holistic approach on food systems gains relevance, there is a lack of data on food systems in the current agricultural censuses. Also, modelling tools with a multilevel territorial approach are needed for food system dynamics and risk management. Food systems research presumes the involvement of players from the food chain to researches related to the Farm to Fork Strategy. The research on the social, poverty and demographic problems related to food systems should not be neglected. Therefore, synchronisation of research within the most important issues pertaining to sustainable food systems is necessary.

MAIN RESEARCH TOPICS:

RT 3.1: Developing monitoring and statistics systems for environmental, biodiversity and natural capital

RT 3.2: Food system dynamics modelling and risk management at different territorial levels

RT 3.3: Advisory services, data and knowledge transfer and skills for future sustainable food systems

RT 3.4: Better understanding of planetary boundaries to facilitate innovative solutions for sustainable and circular management and use of natural resources as well as the prevention and removal of pollution

RT 3.5: Releasing the potential of digitalisation in the food systems

RT 3.6: Governance of innovation ecosystems for circularity in food systems

EXPECTED OUTCOME AND IMPACT

As a result of the outlined research topics, new sources of information will be utilised in food systems monitoring and research, e.g., social media analysis as a data source and platforms. National statistical databases and analyses will be enhanced so that they provide for analysis of food systems. A knowledge and information transfer system will be developed that allows for analysing signals from the market and from the production of the agri-food sector on an ongoing basis, and then creates or adapts solutions to emerging problems and supports their transfer to economic practice.

TA4: PROMOTING SUSTAINABLE FOOD CONSUMPTION AND THE SHIFT TO HEALTHY, SUSTAINABLE DIETS

CHALLENGES:

Increasing consumer awareness of food quality, agroecology, organic farming, how to make healthy and sustainable choices, and short value chains remains a challenge in the BIOEAST region. Along with this, there is a need to increase public awareness of how to reduce food waste and use by-products made from waste biomass. This could open pathways for new industries for healthy life and food (e.g., new bio-technologies with direct application for a healthy lifestyle). Currently, limited progress has been achieved on collective knowledge on new paths for development: microbiome, food from the oceans, urban food systems, source of alternative proteins, meat substitutes.

MAIN RESEARCH TOPICS:

RT 4.1: Reformulation of processed food, including the setting of maximum levels for certain nutrients

RT 4.2: Monitoring framework for responsible business and marketing conduct in the food supply chain

RT 4.3: Revision of EU marketing standards for agricultural, fishery and aquaculture products to ensure the uptake and supply of sustainable products

RT 4.4: Educational framework for sustainable food use and the shift to sustainable diets

EXPECTED OUTCOME AND IMPACT

The above-mentioned research topics will contribute to strengthening the share of domestically produced goods in overall consumption, and lead to a decline in the proportion of the obese population. The number of consumers with a healthier and more environmentally conscious attitude will increase. Meat will partially be replaced with vegetable protein sources. Through rural facilitator networks and knowledge hubs, the knowledge of digitisation and technology, new trends and channels are made available to participants in the local food system. A strong evidence and information base will be established for regional/national strategies and a regulation will be determined, that will systematically, within the deadline of a few years, eliminate or significantly reduce the consumption of the most resource demanding foods, like e.g., processed food.

CORE THEME 4:
BIOENERGY AND NEW VALUE-ADDED MATERIALS

Strategic Thematic Area:

TA1: Integrating bioenergy in circular and sustainable bioeconomy
TA2: Biomass supply and utilisation upgrade for climate change mitigation
TA3: Streaming biofuels towards decarbonisation of national economies
TA4: Role of bioenergy in climate-neutral bioeconomy

TA1: INTEGRATING BIOENERGY IN CIRCULAR AND SUSTAINABLE BIOECONOMY

CHALLENGES

Several major challenges have been identified in terms of integrating bioenergy into a sustainable circular bioeconomy: 1) bioenergy policies are framed too narrow and only from the energy policy domain. The multiplier effect and possible benefits from novel value chains for secondary biomass or abandoned land remain idle, with little benefits to the rural areas; 2) high costs and lack of financial support. Without measures accounting for the negative impacts of fossil fuel burning, most bioenergy options have a higher cost than fossil fuels; 3) Lack of awareness of bioenergy side stream values.
About 75% of the EU's anthropogenic GHG emissions are assigned to fossil fuel combustion. At the same time, current bioenergy facilities have linear business models that fail to maximise the substitution effect of supplying renewable carbon. While sustainable business models are a subordinate category to some bioeconomy business models, not all bioeconomy business models are currently sustainable. If no emphasis is attributed to circularity, bioenergy is at risk of becoming a 'business as usual' scenario. This means that we have the assignment to design an appropriate business models for a novel bio-based technology to abandon fossil resources and push bioenergy facilities towards circularity and sustainability.
Bioelectricity is overrun by fuel-less technologies, which are hard to control or dependent on climatic conditions that are becoming more and more unpredictable. Besides bioelectricity, biomass CHPs produce by-products such as bioheat, CO2, and ash (solid biomass) or digestate, sulfur and other substances (biogas), the value of which is not being fully recognised by the market

MAIN RESEARCH TOPICS:

RT 1.1: Circular business models for bioenergy plants with grid balancing

RT 1.2: Increasing circularity and carbon sink via sectoral synergies for bioenergy generation

RT 1.3: New pathways for valorisation of bioenergy production side streams (CO2, ash, fine dust and digestate) as a part of sustainable value chains

EXPECTED OUTCOME AND IMPACT

Expected benefits from circular business model integration include reduced GHG emissions from the agri-food sector by integrating value-added side streams and grid balancing, which is highly disrupted by intermittent renewable energy generation. Bioelectricity is the only renewable energy source that produces base energy, essential in reducing grid balancing costs, allowing grid flexibility, and providing long-term direct and indirect employment in rural areas through biomass demand. In the heating and cooling sector, biomass represents a secure and locally available biofuel, while gaseous and liquid biofuels are mature renewable options for transport. Bioenergy plays an essential role in reducing emissions from heat supply and removing CO2 from the atmosphere when it is combined with carbon capture, utilisation and storage. Circular business models that valorise bioenergy by-products (digestate, ash, fine dust and renewable CO2) and upgrade from anaerobic digestion bioelectricity to biomethane will attract investors who are aware of their role and benefit. Secondary biomass from the agri-food sector is a source of feedstock for bioenergy facilities. Also, bioenergy side streams can be utilised in the agriculture and food industry – e.g., dewatered and pelletised digestate for soil enhancement and purified CO2 for food conservation.

The final aim is to provide support in designing a regulatory framework with the concept of viability within the bioeconomy and consequently energy from biomass. Also, to accelerate and strengthen the regional development of industrial symbiosis and to better understand how business models can be composed for bio-based technologies to materialise and enable a transition to a bioeconomy.

TA2: IMPROVING BIOMASS QUALITY FOR BIO-BASED INDUSTRY

CHALLENGE

Biomass supply has been identified as one of the bottlenecks in developing a large-scale bio-based industry. Mobilising biomass for bioenergy has been limited due to the high feedstock price and reflects the costs of activities along the biomass supply chain, including biomass loss during storing, versus 'affordable' energy prices. The biomass supply chain for a sustainable circular bioeconomy is not much different than extensively elaborated supply chains under agri-food and bioenergy: the main elements of harvesting and collection, pre-treatment, storage and transport remain the same, where the last component of biomass use is expanded from food/feed/beverage or bioenergy to bio-based materials, chemicals, fibres and advanced fuels, either as a single or a bundle of bio-based products. Biotechnology could be deployed along the value chain to provide support for the development of bio-based industries in such a way as to ensure the sustainability of the sectors and to reduce negative environmental impacts that might otherwise occur. Beyond this, it is also essential to avoid unnecessary waste and to recycle unavoidable waste in useful and efficient ways.

The energy sector is a highly regulated sector of large volumes that aims to produce stable, secure and affordable energy for all, pushing the biomass owner to the bottom of the bioeconomy product pyramid. Suppose a biomass owner is to climb up the bioeconomy pyramid from 'only bioenergy' to 'a bioenergy in a cascading use'. In that case, biomass must be priced by its properties (e.g., lignin, bioactive molecules) that serve as demand in novel bio-based value chains. Stabilising biomass supply by quality and quantity reduces uncertainty for investments in bio-based SMEs and industries. A sustainable circular bioeconomy can capitalise on the vast knowledge of biomass supply chains for bioenergy to stabilise biomass supply and ensure its sustainability.

The main challenges remain a lack of awareness of sustainability requirements in the biomass and bioenergy-related sectors, uncertainty, seasonality of supply, costs and competitiveness. These challenges can be tackled under the umbrella of the research topics enlisted.

MAIN RESEARCH TOPICS:

RT 1.1: Sustainable biomass sourcing and collection for efficient bioenergy production

RT 1.2: Establishment of national collection hubs for the valorisation of future biomass pathways

RT 1.3: Post-harvesting techniques to enhance biomass quality for bio-based energy

RT 1.4: Capacity building in terms of sustainable management and utilisation of secondary biomass potential for bioenergy production

EXPECTED OUTCOME AND IMPACT

In general, the main outcomes are to ensure value chain sustainability, supply sufficient quantities of renewable raw materials and energy, reduce environmental footprints and promote a healthy and viable rural economy. A stable biomass supply for circular sustainable bioeconomy and the cascading use of biomass in the BIOEAST macro-region with consolidated data on quantities, quality and origin of biomass for the BIOEAST macro-region is one of the main outcomes.

Through the establishment of collection hubs, the goal is to maximise the utilisation of underutilised secondary biomass sources with the direct impact of reducing risks of climate change effects on the environment. Also, it is expected that these collection hubs (agri-bio-hubs) are either set up at the ex-

isting post-harvest facilities or as new locations that provide access points to the sustainable-sourced, secondary biomass market. Biomass loss is minimised, whereas desired (marketable) biomass properties are enhanced while storing. Significant opportunities also exist in increasing supply chain efficiencies through technology transfer (from regions with well-developed supply chains to regions with minimal bioenergy deployment) and learning-through-doing. Another benefit is unlocking and enabling quantities for setting up the conversion processes to produce a broader range of end products, whether food, feed, fuel, fibre or other healthcare or industrial products. The foreseen approach envisages the development of a buffer to stabilise biomass supply and demand to deliver biomass at a certain quality to the industry with maximisation of the biomass value.

It is expected to boost local employment via the integration of harvesting techniques and valorisation of scattered biomass sources regarding location, electricity and gas infrastructure for novel bio-based value chains.

The integration of proposed research topics on the demonstration/flagship level is expected to lead to strong local impacts. This is because they are based on local supply and typically develop an added value for local farmers, forest managers and industries by valorising the residues, by-products and waste of their core business. In addition to the local impact, the expanded view of the local region and the ability of biomass to integrate and service multiple markets were seen as offering a sustainable local impact.

TA3: STREAMING BIOENERGY TOWARDS DECARBONISATION OF NATIONAL ECONOMIES

CHALLENGE

The decarbonisation of national economies represents many challenges. The challenge to reduce GHG emissions involves a combination of reductions in the energy demand, increases in energy efficiency, electrification of the end-use and establishment of a high share of renewable energy. There is no global measure to cut emissions, and each country must implement individual measures. In line with the European Green Deal, European countries are striving to become climate-neutral by 2050, but at the same time they are failing to utilise the national potentials of bioenergy sources to decarbonise their economies.

Wood-related territorial capital is significant in the Baltic states, Slovenia, Slovakia, Poland, Czechia and Croatia. Sankey diagrams of the EU biomass flows indicate that all the BIOEAST countries aside from Hungary and Poland are net exporters of roundwood and wood pellets. The Baltic states are at the strongest imbalance in missing the opportunity to defossilise their economies with renewable carbon from forest-based biomass and reduce the GDP gap with greater value-added wood-based products. To maximise national economic sustainability and to achieve the 'zero waste' policy, biofuel production can be paired with the bio-chemical industry in cascading use via direct or inverse mode. In the direct mode, the biomass is first used to produce added-value bioproducts, and afterwards the remaining residues of these processes are subjected to bioenergy-generating processes. In the inverse cascading, the biomass enters a bioenergy-bioproduct-bioenergy approach. The selection of cascading type depends on regional/national needs and priorities.

Transport biofuels could allow for a deeper decarbonisation of aviation, shipping and heavy-duty transport, as these are likely to remain reliant on liquid carbon-based fuels in the longer term. Also, using local biomass for electricity and heat would lead to a greater GHG emissions reduction and subsequently to national decarbonisation. Separated CO2 can be captured and utilised in CO2-intensive industries, reacted with the addition of electrolytic hydrogen in methanation units or stored with carbon capture and storage. While the carbon capture and utilisation concept is aligned with circular economy principles and treats CO2 as a resource rather than waste, most carbon capture and utilisation options do not entail the permanent sequestration of carbon. The use of carbon capture and utilisation via Power-to-X pathways to generate various biofuels, such as methane, methanol or jet fuels, could bring economic benefits and support electricity grid balancing, thereby reducing the need for direct electricity storage.

The choice of implemented bioenergy technology should closely connect with biomass potential and availability. To revitalise local economies, bio-based projects should be developed near the sources of biological resources.

MAIN RESEARCH TOPICS:

RT 1.1: Pairing biofuels production with bio-chemicals in cascading use

RT 1.2: Integration of national bioenergy in energy and emission-intensive sectors

RT 1.3: Developing local, small-scale bio-communities for rural sustainable circular bioeconomy ecosystem

EXPECTED OUTCOME AND IMPACT

The expected outcome is to mainstream biofuels for heating and cooling and in the transport sector with binding sustainability criteria (Articles 23 31, of RED II). Pairing biofuels with bio-based chemicals in cascading use or biorefineries, and outlining highly replicative business models for short supply chains, would boost more local value-added while defossilising national economies. Carbon capture and utilisation technologies can help secure the energy supply by reducing the dependence on fossil fuels by enabling the potential to produce fuels, chemicals and materials.

The goal is also to raise awareness of the importance of decarbonising one's own economy. This contributes to the national value and the achievement of goals at EU level. Achieving these mandated renewable energy goals can be done with the increased participation of BIOEAST stakeholders in CBE JU funded activities.

TA4: ROLE OF BIOENERGY IN CLIMATE-NEUTRAL BIOECONOMY

CHALLENGE

Circulating biomass in the bio-based industry allows for unbundling growth from resources. In contrast, the sustainability of the bio-based industry must be secured by involving and engaging all value chain actors, renewable energy generation and environmentally less-intensive chemistry. Methane strategy is essential for BIOEAST region, as meat, dairy and egg products generate much GVA to the national economies. One of the main challenges is to find sustainable, innovative solutions for curbing the methane emissions from the livestock sector. This is where social goals (GHG emission savings) are overlapping with economic goals (farmers' increased competitiveness) and environmental goals (returning the nutrients to the cycle by producing organic fertiliser from manure-based anaerobic digestion).

Mature bioenergy technologies are increasing their contribution to reducing CO2-eq emissions with carbon capture and storage concepts. Such concepts envisage extracting bioenergy from biomass and capturing and storing the carbon, thereby removing excess CO2 from the atmosphere, or enhancing the efficiency energy system (an EU strategy on energy system integration). Harmonising demand for biomass for bioenergy with other bioeconomy sectors and securing the cascading use of biomass will unlock the opportunity for larger scale carbon capture and storage. While bioelectricity is the most expensive renewable source, it is also the largest employer in the RES sector, using only biomass with simultaneous circularity and sustainability. Pairing it with other Green Deal goals can produce a desired ripple effect.

Some of the identified challenges are regulations for technologies within the emerging bioeconomy that are often and still unclear or misaligned, leading to uncertainty and conflicting incentives. These challenges reflect the particularities of bioenergy within the bioeconomy, such as the complex knowledge base, commercialisation issues and fragmented policy schemes. Furthermore, the commercialisation and transfer of technologies into the market remains a difficult endeavour and for newly developed technological solutions upscaling remains a critical challenge. For substitute technologies such as power-to-gas or hydrogen technologies, in particular, compatibility with the current infrastructure of the fossil-based system is crucial to value generation.

MAIN RESEARCH TOPICS:

RT 1.1: Harmonising bioenergy mandated shares in energy policy with emerging bioeconomy value chains

RT 1.2: Biomethane and hydrogen production in the BIOEAST macro-region as a tool for decarbonisation of fossil-based industry

RT 1.3: Enhancement of efficiency via the inclusion of carbon capture and storage technologies in bioenergy production in the BIOEAST macro-region

R.T.1.4. New and emerging technologies of biomass conversion for the purpose of energy storage with the aim of balancing, diversifying and securing energy supply

R.T.1.5. Possibilities of support system and policy framework for future bioenergy project development

EXPECTED OUTCOME AND IMPACT

In order to ensure a climate-neutral bioeconomy, it is crucial to foster the transcription of mature technologies with a strong focus on innovation through research and technology development, a systemic structure and a significant degree of interdisciplinarity with empowered cooperation between identified key actors. This strategic thematic area identifies and recognises the benefits of sector coupling as a technological way to reach EU Green deal goals and the other strategy goals set for the upcoming years. Furthermore, these research topics should raise questions and problems detected regarding energy independence, stability in EU energy supply and decarbonisation of different sectors. Technology development and research results should provide and facilitate policy-making to ensure sustainability throughout value chains and impact projections on future energy mix, including renewable sources of gas and planned measures in the area of the energy system's resilience.

The expected outcome is a ripple effect where the most important GVA sectors of BIOEAST economies (e.g., meat and dairy sector, beer industry etc.), as well as emerging bio-based industries (biochemicals, bioplastics, rubber and biopharmacy), are defossilised by sector coupling in addition to accomplishing RED II and REPowerEU goals in providing stability in the EU energy supply.

CORE THEME 5:
ADVANCED BIOCHEMICAL AND BIOMATERIALS

Strategic Thematic Areas:

- TA1: Assessment and valorisation of sustainable feedstocks for the chemical industry
- TA2: Blue economy in the production of bio-based chemicals and materials
- TA3: Chemical and enzymatic transformation of biomass
- TA4: Production of bioactive and functional compounds
- TA5: Production of bio-based materials and platform chemicals
- TA6: Innovative high-value bio-based products for demanding applications

TA1: ASSESSMENT OF SUSTAINABLE FEEDSTOCKS FOR THE CHEMICAL INDUSTRY

CHALLENGES

Bioeconomy is a broad concept that aims to achieve the valorisation of bio-based resources in various ways. Large amounts of primary and secondary biomass are produced in CEE (e.g., in agriculture, forestry and the food industry) that could serve as raw materials for biotechnological conversion. The relevant value chains, however, are not yet fully developed. Several challenges need to be addressed to achieve the transition of the chemical industry from fossil-based feedstocks to renewable ones. These involve the availability of biomass and industry side streams, technological challenges, as well as the necessity of avoiding competition with food and feed applications.

MAIN RESEARCH TOPICS

RT 1.1: Mapping available biomass supplies for valorisation in the chemical industry

RT 1.2: Boosting the formation of bioeconomy clusters along promising value chains

RT 1.3: Analysing the generation of food waste along the whole value chain

RT 1.4: Exploring value chains based on non-wood forest products

RT 1.5: Development of new varieties of fibre and oil plants for industrial applications

RT 1.6: Improved medicinal plant varieties to produce bioactive compounds

RT 1.7: Implementing effective microorganisms for the stimulation of growth in industrially relevant plants

EXPECTED OUTCOME AND IMPACT

Sustainable indicators and monitoring systems for the whole biomass value chain will be developed and implemented. Currently available value chains will be improved, while new ones will also be created, with respect to the 'food first' and 'cascading use' principles. Biomass or waste streams that cannot be utilised by the food and feed sectors will be channelled towards other relevant actors in the chemical industry and industrial biotechnology. Enhanced biodiversity and more sustainable crop production will be achieved through new plants varieties and with the aid of microorganisms.

TA2: BLUE ECONOMY IN THE PRODUCTION OF BIO-BASED CHEMICALS AND MATERIALS

CHALLENGES

The concept of blue economy originates from that of green economy, with its focus being the sustainable management of 'blue' resources and the valorisation of renewable aquatic and marine feedstocks. It may offer significant opportunities to produce a range of valuable chemicals (food additives, dietary supplements, pharmaceuticals, cosmetics) and materials through innovative processes. Blue economy value chains, however, are generally underdeveloped in CEE countries. Many challenges still need to be resolved in policy making, research, production and in terms of end-of-life strategies.

MAIN RESEARCH TOPICS

RT 2.1: Assessing the opportunities and limits of CEE blue bioeconomies towards the production of bio-based chemicals and materials

RT 2.2: Exploring waste generation and waste management options in aquaculture and symbiotic (plant/fish) production systems

RT 2.3: Analysing valorisation options for aquaculture side- and co-products along the existing value chain

RT 2.4: Developing new strategies and technologies for the conversion of aquaculture waste and side streams into bio-based chemicals and materials

EXPECTED OUTCOME AND IMPACT

Aquatic biomass waste streams will be identified, and promising raw materials utilised, that broaden the range of available bio-based raw materials for the chemical industry. Fisheries and other first stage aquatic biomass producers will be able to improve their profitability due to additional revenue streams. Sustainable aquaculture production will lead to job creation and new opportunities for businesses, while enabling them to shift their product portfolios towards sustainable bio-based products.

TA3: CHEMICAL AND ENZYMATIC TRANSFORMATION OF BIOMASS

CHALLENGES

The conversion of biomass into valuable products is a challenging process. It involves various pre-treatment steps, extraction, chemical and biological conversion, as well as downstream processes, e.g., purification and derivatisation. Factors such as biomass composition and origin, available infrastructure, environmental impact and the expected demand for the potential end-products need to be considered. Relevant technologies must be further developed, and new ones invented, to improve the efficiency of this complex process. At present, crucial infrastructure is still lacking in CEE in terms of available biorefinery capacities, despite the presence of considerable knowledge and expertise that may facilitate technological innovations.

MAIN RESEARCH TOPICS:

RT 3.1: Advanced enzymatic/fermentative processes for high-value products

RT 3.2: Mapping existing technologies to convert CEE agricultural and food industry side streams into bio-based chemicals and materials

RT 3.3: Establishing pilot and demo scale biorefineries

RT 3.4: Converting biomass into natural and bio-based polymers

RT 3.5: Versatile platform for the valorisation of glycerol side streams from biodiesel production

EXPECTED OUTCOME AND IMPACT

Small- and intermediate-scale biorefineries will be established in CEE, enabling the scaling up of newly developed processes by the academic and industrial sectors. Innovative conversion technologies with a favourable environmental impact will be developed and tailored to the utilisation of local biomass sources, resulting in the creation of new value chains and the reorganisation of current value networks. First stage biomass producers will be better integrated into the bioeconomy as suppliers of renewable resources to provide bio-based alternatives to fossil-based materials and platform chemicals.

TA4: PRODUCTION OF BIOACTIVE AND FUNCTIONAL COMPOUNDS

CHALLENGES

Beyond its main constituents (cellulose, hemicellulose and lignin), plant-based biomass contains a wide range of valuable ingredients in large quantities. Residues of herbs and spices, for instance, may provide bioactive substances for the medical, pharmaceutical and cosmetic industries. The biological activity and functional characteristics of many bio-based compounds, however, are not yet fully understood. Moreover, strategies for their extraction, purification, conversion and application need to be developed first at the laboratory, then at an industrial scale.

MAIN RESEARCH TOPICS:

RT 4.1: Bioactive compounds from agricultural and food industry side streams

RT 4.2: Bio-based additives for the plastics industry

RT 4.3: New bioactive compounds from medicinal plants

RT 4.4: Lignin-based antioxidants, food additives and glues

RT 4.5: High-value bio-based products from region-specific plants

EXPECTED OUTCOME AND IMPACT

Through developments related to bioactive and functional compounds, circular bio-based solutions will be achieved, particularly in areas where the substitution of conventional molecules is challenging at present, such as in the pharmaceutical industry, cosmetics and other fine chemicals sectors. New solutions will be identified to valorise food, feed and floral waste through extracting small amounts of high-value components. The investigation of bio-based functional molecules and novel feedstocks will facilitate the transition from fossil-based chemicals to bio-based ones in the chemical industry.

TA5: PRODUCTION OF BIO-BASED MATERIALS AND PLATFORM CHEMICALS

CHALLENGES

Due to its limited supply, the efficient utilisation of biomass, including the valorisation of side streams, is crucial. Large amounts of potentially valuable plant-based fibre, polysaccharide and protein feedstocks are currently thrown away as waste at the end of existing value chains, without being converted into materials and chemicals. Amidst growing environmental, social and economic pressure, there is an urge to develop and implement new solutions for the valorisation of these untapped biomass fractions and turn them into sustainable products.

MAIN RESEARCH TOPICS:

RT 5.1: Improved microbial polyesters as a sustainable solution for the plastics industry

RT 5.2: Bio-based materials and chemicals through the holistic utilisation of fibre plants

RT 5.3: Bio-based binders, adhesives and polyols from wood industry waste streams

RT 5.4: Bio-based polyurethane materials for thermal insulation

EXPECTED OUTCOME AND IMPACT

Improved circularity will be achieved through the utilisation of waste and side streams, by substituting and complementing fossil-based resources, to produce bio-based materials and chemicals. The development of novel materials and solutions for the chemical industry will contribute to the sustainable development goals, supporting business growth and job creation while simultaneously addressing current societal and consumer needs.

TA6: INNOVATIVE HIGH-VALUE BIO-BASED PRODUCTS FOR DEMANDING APPLICATIONS

CHALLENGES

There are several novel application areas (biomedicine, nanomaterials, battery technology, space technology, etc.) with new types of challenges that require a targeted approach. Sustainability is key to finding long-term solutions and this highlights the importance of bio-based materials and chemicals. In some cases, such as healthcare, biomaterials may even provide additional, unique benefits due to their biocompatibility and degradability. Nonetheless, considerable RDI effort is still needed to overcome the difficulties such materials currently face in demanding applications.

MAIN RESEARCH TOPICS (RT):

RT 6.1: Biocompatible, bioactive and degradable materials for medical applications

RT 6.2: Bio-based rigid polyurethane foams as cryogenic insulation materials

RT 6.3: Bio-based active carbon materials for supercapacitors

RT 6.4: Micro and nano-cellulose as building blocks for bioactive materials

EXPECTED OUTCOME AND IMPACT

Long-term sustainable solutions will be achieved by introducing bio-based materials and processes to product development from the very beginning. New technologies will be developed based on the unique characteristics of biomaterials, providing innovative products for demanding applications. Focusing on truly novel, emerging fields of application will ensure that sustainable solutions become the norm, setting good examples for future developments.

CORE THEME 6: FRESHWATER BASED BIOECONOMY

CHALLENGES

The EU faces emerging geopolitical and global challenges, war in Ukraine, food, energy, self-sustainability, resilience and recovery, while at the same time there is an urgent need to face the risks associated with losing the health of the ecosystem after decades of intensive damaging. A responsible smart transition process is needed that leads Europe to a knowledge-based society strongly oriented towards circularity and sustainability. Fresh water is a vital element that influences the economies and social structure of certain regions in the EU. The last European Water Report showed that around 60% of European surface waters (rivers, lakes and transitional and coastal waters) are not in good ecological status and 62% are not in good chemical status. The majority of BIOEAST water bodies have worse than good status; thus, a further acceleration of action by Member States is urgently needed. The BIOEAST macro-region needs to urgently tackle the following issues: the damming of water bodies and changes in hydromorphology, agricultural diffuse pollution, the application of nature-based solutions that reduce water use, promoting the wider use of drought management plans.

MAIN RESEARCH TOPICS

RT 1.1: Nature-based innovative solutions to mitigate the impact of climate change on water ecosystems and improvement of water management.

RT 1.2. Ecosystem-based approaches for improvement of water quality and pollution prevention

RT 1.3. New business models and value chains based on fresh water

RT 1.4. Innovative solutions and support of the innovation ecosystem in the Danube River Basin

EXPECTED OUTCOME AND IMPACT

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.

CORE THEME 7: BIOECONOMY EDUCATION

CHALLENGES

New European economic strength and growth are being built based on a new concept including the valorisation of natural resources and human manpower in a sustainable way. Those are the concepts of bioeconomy, bio-based economy and circular economy, which are becoming key elements in future development. In the forthcoming years, more and more processes will be designed on these principles. The current challenges the EU faces, such as the climate, energy, safety and food crises, place additional pressure on business and the need to look for alternative solutions. Likewise, policy makers are facing new decision-making tasks. Therefore, it is expected that both training modules for professionals and public bodies will reflect these changes in systemic changes to prepare a new generation of entrepreneurs and a skilled workforce.

The role of industry can be catalytic. For an effective educational frame, it is necessary for industry to engage in the programmes and increase the accessibility of students. This, in turn, will guarantee a robust pipeline among industry, faculty staff and students. Our objective is to penetrate new markets, and the ultimate goal is to enhance the opportunities for market penetration for newly educated staff. To achieve this goal, issues like technology forecasting, market requirements, international competitiveness, mobility in transnational and trans-sectoral levels, cooperation with non-European markets, etc. should be analysed and incorporated into the educational mechanisms.

MAIN RESEARCH TOPICS

RT 1.1: Mapping the bioeconomy education landscape in the CEE macro-region

RT 1.2: Identifying regional priorities

RT 1.3: Coordination of actions and facilitating the BIOEAST UNI NET

RT 1.4: Emphasising vocational training

RT 1.5: Innovative governance on bioeconomy education

RT 1.6: Tutorials to support green public procurement and other instruments

EXPECTED OUTCOME AND IMPACT

The BIOEAST Foresight exercise in 2021 detected an asynchronous development in structuring bioeconomy education – the ability of effectively implementing the Green Deal and other EU strategies. Alignment of the educational perspective with European practices, re-organisation of the curricula and prioritising regional needs and expectations, and selecting specific target groups will offer a solid potential for improvement across all levels (technological, economic social and regulatory), and the educational curricula should consider the development of soft skills in addition to disciplinary knowledge. Further education and lifelong learning must be considered by educators according to the new requirements.

Additionally, including the educational perspective in concrete regional planning with specific governance might enhance the perspective of strategy adoption at national level.
In the mid to long term coordinated actions on a regional basis (e.g., co-organised vocational training or the creation of a Regional Institution) could be a goal.

4 THE EU's ADDED VALUE

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

- 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,
- EU policy priorities implemented (Table 6),
- a smaller gap between the BIOEAST macro-region and the EU innovation leaders,
- unlocked sustainable circular bioeconomy potential.

The BIOEAST Foresight Exercise[22] 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 with value added for the region would make the following impacts.

IMPACT ON ECONOMIC DEVELOPMENT AND GROWTH LEVELS

In general, the adoption of bioeconomy principles will have a direct impact on economic development and growth in both the short- and mid-terms. Besides this, the potential investments will be observed, and an alignment to common European practices as well as 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 and consortia, and more. Indirect economic impact will be achieved by adopting practices such as biomass valorisation, enabling new value chains, circularity, sustainable production lines and the cooperation of various sectors, among others.[23]

IMPACT ON COMPETITIVENESS

Given that sustainability is a key element in all bioeconomy practices, sustainable development will become a mandatory path and will support practices and actions involving it in all domains. Sustainability will make the regional economy more competitive by supporting not only bioeconomy-related pathways but also lateral 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, the alternativite value chains, complementarity, competitiveness, and the homogeneity of attitudes and perceptions, as well as development and growth. The opinion is that the CEE region should reach the standards of Northern and Western Europe in terms of competitiveness, market exploration, growth and attracting investments. Collaboration is essential for the implementation

22, 23 BIOEAST Foresight Exercise Group of Experts. 2021. BIOEAST foresight exercise report (Deliverable 3.4.).

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.[24]

IMPACT ON SOCIETAL LEVEL

Job creation 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.[25]

ENVIRONMENTAL IMPACT

A bioeconomy approach is based on sustainability, so the environmental impact of full implementation is certainly positive. The circular character of the process further enhances this positive impact.[26]

After summarising the expected outcomes designed by the Thematic Working Groups and the impacts of Strategic Thematic Areas (Table 7), we can forecast that implementing the BIOEAST SRIA would contribute to achieving:

- the BIOEAST Initiative long-term goals,
- several BIOEAST Initiative general objectives,
- as well as the BIOEAST 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*.

The Strategic Thematic Areas of the BIOEAST SRIA are quite broad; therefore, multiple partnerships and missions may be in the focus of the Thematic Working Groups. According to the Strategic Thematic Areas identified, the Thematic Working Groups have links to the following European Partnerships and HE Missions (Table 8):

- 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,

24, 25, 26 BIOEAST Foresight Exercise Group of Experts. 2021. BIOEAST foresight exercise report (Deliverable 3.4.).

- 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.

Figure 15 shows the Monitoring Framework for the BIOEAST SRIA and interconnections between the expected benefits that indicate which elements of the monitoring framework relate to the benefits for the European Union.

The link of monitoring framework elements with the BIOEAST Initiative objectives is shown Annex 2 (column 1).

Based on the identified complementarity and interaction of:

- the BIOEAST Vision for 2030 and long-term goals with the EU's main strategies and action plans
- the Strategic Thematic Areas with the EU's aims and strategies

one can expect that implementing the BIOEAT SRIA and seeking to achieve the BIOEAST Vision for 2030 will add value to the EU's aims and strategies.

A comparative analysis between the goals of the European Union's policies and promotional measures and Strategic Thematic Areas of the BIOEAST SRIA found complementarity and interaction (Table 6). **This means that the BIOEAST SRIA establishes links between several strategies of the EU** (Sustainable bioeconomy for Europe, Farm to Fork Strategy, EU Biodiversity Strategy for 2030, New EU Forest Strategy for 2030, EU Pollinator Initiative, 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. 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.

Table 6: **Complementarity and interaction of the BIOEAST Core Themes with the EU's strategies and action plans**

Strategic Thematic Areas/ Core Themes	EU's Strategies and action plans							
	European Green Deal							
	Sustainable bioeconomy for Europe	New Circular Economy Action Plan	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
	Core theme: **Agroecology and Sustainable Yields**							
TA1: Soil management	x	x	x	x		x	x	x
TA2: Transition to Chemical Pesticide-free Agriculture	x	x	x	x		x		x
TA3: Genetic Resources and Agricultural Diversification	x	x	x	x		x		x
TA4: Innovation, Smart Agriculture, Digitalisation and Knowledge Sharing	x	x	x			x	x	x
TA5: Animal Health and Welfare	x		x	x				x
TA6: Local Food Systems and Rural Development	x	x	x	x				x
	Core theme: **Forestry Value Chains**							
TA1: Forest resources	x			x	x			x
TA2: Sustainable wood production chains	x				x			
TA3: Keeping and further straightening of traditional and development of high-tech wood processing industries					x			
TA4: Biomass and bioenergy	x			x	x		x	
TA5: Paper-pulp technologies	x				x			
TA6: Recycling and cascading system of wood and wood products use		x			x			
TA7: Regional development	x				x			
TA8: Forest services					x			

Legend: x complementarity and interaction | none

Strategic Thematic Areas/ Core Themes	EU's Strategies and action plans							
	European Green Deal							
	Sustainable bioeconomy for Europe	New Circular Economy Action Plan	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
	Core theme: **Food Systems**							
TA1: Sustainable Food Production (PRODUCTION)	x	x	x					
TA2: Power and information in the food system: strengthen the food environments and vulnerable actors in the food chains (FOOD CHAINS)	x		x					
TA3: Research, innovation, technology and investments for future sustainable food systems (RESEARCH)	x	x	x	x				
TA4: Promoting sustainable food consumption and the shift to healthy, sustainable diets (CONSUMERS)			x					
	Core theme: **Bioenergy and New Value-added Materials**							
TA1: Integrating bioenergy in circular and sustainable bioeconomy	x	x				x	x	
TA2: Stability of biomass supply for CSBE with ensured quality, quantity and certified sustainability	x	x				x	x	x
TA3: Streaming biofuels production towards defossilisation of national bioeconomies in the line with the energy union strategy	x	x				x	x	
TA4: Harmonising bioenergy mandated shares in energy policy with emerging bioeconomy value chains	x					x	x	

Legend: x complementarity and interaction | none

Strategic Thematic Areas/ Core Themes	EU's Strategies and action plans							
	European Green Deal							
	Sustainable bioeconomy for Europe	New Circular Economy Action Plan	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
	Core theme: **Advanced biochemical and biomaterials**							
TA1: Availability of sustainable feedstocks from agricultural residues and food industry	x	x	x		x			x
TA2: Chemical and enzymatic transformation of biomass	x	x	x	x	x	x		x
TA3: Production of bioactive compounds	x	x	x	x	x	x		x
TA4: Production of bio-based chemicals and materials	x	x	x	x	x	x	x	
TA5: Innovative high-value bio-based products	x	x			x	x		
TA6: Blue economy in sustainable biochemical production	x	x	x	x				
	Core theme: **Freshwater Based Bioeconomy**							
TA1: Freshwater Based Bioeconomy	x	x	x	x				x
	Core theme: **Bioeconomy Education**							
TA1: Bioeconomy Education	x	x	x	x	x	x		x

Legend: x complementarity and interaction; none

Source: author's construction.

Table 7: **Mapping of main expected outcomes and impacts of the BIOEAST SRIA, objectives of the BIOEAST Initiative and long-term goals the BIOEAST Initiative**

Main expected outcomes and impacts of the BIOEAST SRIA	Related objectives	Related long-term goals of the BIOEAST Initiative
- Improved evidence-based policy making - Available tools, networks and infrastructures for knowledge transfer and motivation of stakeholders - Needs-based and results-oriented RDI	O 2. To cooperate and develop evidence-based policies	
- Developed and introduced sustainable indicators and a monitoring system for the whole biomass value chain - Developed decision support and prediction tools built on the integrated knowledge base - Improvement in the flow of up-to-date information - Broader distribution of processed farm-data	O 4. To provide the evidence base	
- Education curricula for secondary and university studies adapted to trends in the circular bioeconomy - Wider use of IT and digital tools among primary bioresource producers - New competences to sustain a viable rural society	O 5. To improve skills	
- Public awareness raising - Ecolabels (certification and product origin) impact on consumer choices	O 7. To increase visibility	
- Developed systems and procedures for optimisation of biomass production	O 6. To develop synergies	**G 1.1. Productivity:** Sustainable increase of biomass production

Main expected outcomes and impacts of the BIOEAST SRIA	Related objectives	Related long-term goals of the BIOEAST Initiative
- Reduction of the environmental and climatic burdens - Improvement in adaptive capacity to climate change and reduction of vulnerability to climate change - Biodiversity preservation - Sustainable land management - More sustainable livestock farming - Improvement in supplying clean freshwater - Reducing the risk of flooding through nature-based solutions with restoration techniques - Improved and more sustainable gene conservation practice	O 6. To develop synergies	**G 1.2. Sustainability:** Developing biodiversity and biosecurity
- Dissemination of the sustainable circular economy approach in bioeconomy industries - Replacement of fossil raw materials with organic ones - Widening the range of available bio-based raw materials for the chemical industry - Developed novel technologies that are tailored for the utilisation of local biomass sources - Developed small-scale biorefineries in the CEE region, which can be utilised by the academic and the industrial sector - Enhanced currently available biomass value chains, as well as newly created and effective value chains - Aiding businesses to shift their portfolio towards bio-based, more sustainable products - Identification of new sources of revenue for primary bioresource producers, as well as opportunities to expand their product portfolio - Development of industrial symbiosis	O 6. To develop synergies	**G 2.1. Resource efficiency:** Circular and value-added use of the available biomass
- Diversified rural production and increased self-sufficiency at local levels - Strong rural and local communities, increased prestige of rural life - Territorial (local/regional) bioeconomy systems to support regional development and sustainability - New value-added jobs to sustain a viable rural society	O 6. To develop synergies	**G 2.2. Rural development:** Increasing viability and attractiveness of rural areas and society

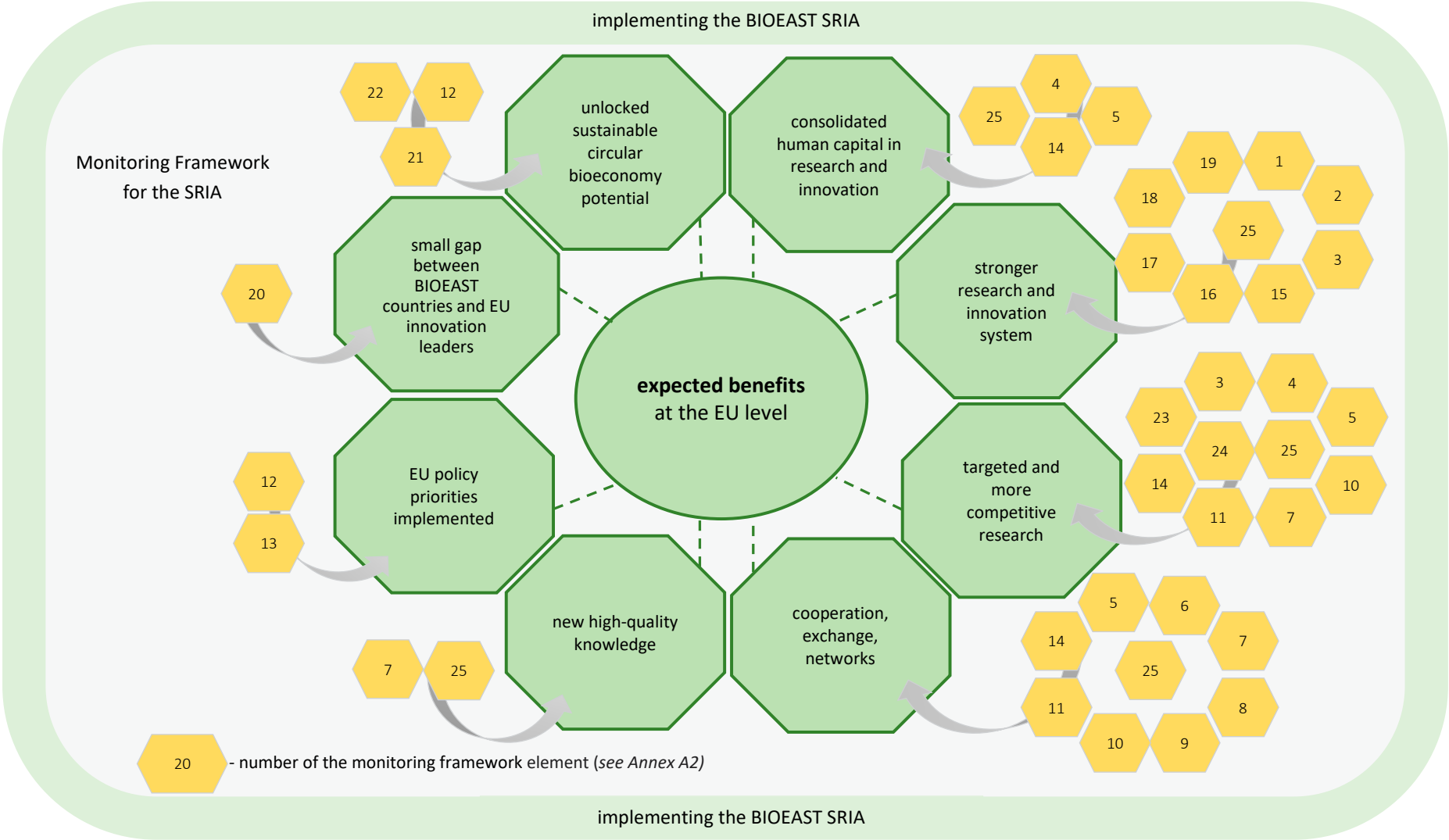
Source: Thematic Working Groups, 2022.

Table 8: **Mapping of the Thematic Working Groups, European Partnerships and HE Missions**

Thematic Working Groups	European Partnerships											HE Missions		
	Circular Bio-based Europe Joint Undertaking (the CBE JU Partnership)	European Biodiversity Partnership: Biodiversa+	Accelerating Farming Systems Transition	Animal Health and Welfare	Agriculture of Data	Rescuing Biodiversity to Safeguard Life on Earth	A Climate Neutral, Sustainable and Productive Blue Economy	Safe and Sustainable Food Systems for People, Planet & Climate	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)	Adaptation to Climate Change	Healthy Oceans, Seas, Coastal and Inland Waters	Soil Health and Food
Agroecology and Sustainable Yields		x	x	x	x			x							x
Forestry Value Chains					x								x		x
Food Systems					x			x							x
Bioenergy and New Value-added Materials										x	x	x	x		
Advanced Biochemical and Biomaterials	x	x			x		x							x	
Freshwater Based Bioeconomy						x	x		x				x	x	
Bioeconomy Education					x										

Source: Thematic Working Groups, 2022.

Figure 15: **Added value of the proposed actions of the BIOEAST SRIA at the EU level**



Source: author's construction.

REFERENCES

Ahmad, N., Bohn, T., Mulder, N., Vaillant, M., Zaclicever, D. 2017. Indicators on global value chains, OECD Statistics Working Papers 2017/08.

Baldoni, E., Reumerman, P., Parisi, C., Platt, R., González Hermoso, H., Vikla, K., Vos, J., M'barek, R. 2021. Chemical and material driven biorefineries in the EU and beyond. Publications Office of the European Union. ISBN 978-92-76-34252-6, doi:10.2760/8932, JRC124809.

BIOEAST Agroecology and Sustainable Yields Thematic Working Group. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Food Systems Thematic Working Group. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Forestry Value Chain Thematic Working Group. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Thematic Working Group Advanced Bio-based Chemicals and Materials. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Thematic Working Group Bioenergy and New Value-added Materials. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Thematic Working Group Fresh Water Based Bioeconomy. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Thematic Working Group on Bioeconomy Education. 2022. Thematic Strategic Research and Innovation Agenda.

BIOEAST Foresight Exercise Group of Experts. 2021. BIOEAST foresight exercise report (Deliverable 3.4.).

BIOEAST Vision & Objectives. Available at: https://bioeast.eu/vision-objectives/

BIOEAST. 2018. BIOEAST Vision paper. Available at: https://bioeast.eu/download/bioeast_vision_paper_23022018/

BIOEAST. 2020. Framework for the SRIA development (Deliverable 4.1).

BIOEAST. 2020. Report on analysis of BIOEAST national bioeconomy related sectors (Deliverable 1.2).

BIOEAST. 2021. Bioeconomy institutional profiles - comparative analysis, benchmarking and policy recommendations (Deliverable 1.4).

BIOEAST. 2021a. Report on the state-of-the-art innovation gaps and needs of the bioeconomy-related R&I in BIOEAST macro-region (Deliverable 4.2).

DataM. 2022a. Bio-based industry. Available at: https://datam.jrc.ec.europa.eu/datam/mashup/BIOBASED_INDUSTRY/index.html

DataM. 2022b. Biomass Flows. Available at: https://datam.jrc.ec.europa.eu/datam/mashup/BIOMASS_FLOWS/

DataM. 2022c. Chemical and material biorefineries in the EU. Available at: https://datam.jrc.ec.europa.eu/datam/mashup/CHEMICAL_BIOREFINERIES_EU/

ERA-LEARN. [s.a.]. Guide for the SRIA Development Process. Available at: https://www.era-learn.eu/support-for-partnerships/additional-activities/strategic-research-and-innovation-agendas/guide-for-the-sria-development-process

ERA-LEARN. [s.a.]. Strategic Research and Innovation Agendas. Available at: https://www.era-learn.eu/support-for-partnerships/additional-activities/strategic-research-and-innovation-agendas

European Climate Law. https://ec.europa.eu/clima/policies/eu-climate-action/law_en

European Commission. [s.a.]. Blue bioeconomy and blue biotechnology. Available at: https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/blue-bioeconomy-and-blue-biotechnology_en

European Commission. [s.a.]. Forest – new EU strategy. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12674-Forests-new-EU-strategy

European Commission. 2017. Biomass flows in the European Union. Available at: https://joint-research-centre.ec.europa.eu/jrc-news/biomass-flows-european-union-2017-06-13_en

European Commission. 2018. A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy. Available at: https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1

European Commission. 2019. The European Green Deal. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN

European Commission. 2020. A Farm to Fork Strategy: for a fair, healthy and environmentally-friendly food system. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590404602495&uri=CELEX%3A52020DC0381

European Commission. 2020. A new Circular Economy Action Plan: For a cleaner and more competitive Europe. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

European Commission. 2020. A New Industrial Strategy for Europe. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1593086905382&uri=CELEX%3A52020DC0102

European Commission. 2020. EU Biodiversity Strategy for 2030: Bringing nature back into our lives. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX%3A52020DC0380

European Commission. 2020. EU Biodiversity Strategy for 2030: Bringing nature back into our lives. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX%3A52020DC0380

European Commission. 2020. European Climate Pact. Available at: https://europa.eu/climate-pact/system/files/2020-12/20201209%20European%20Climate%20Pact%20Communication.pdf

European Commission. 2020. Powering a climate-neutral economy: An EU Strategy for Energy System Integration. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN

European Commission. 2020. Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562

European Commission. 2021. New EU Forest Strategy for 2030. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52021DC0572

European Commission. 2021. Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:82:FIN

European Commission. 2022. The bioeconomy in different countries. Available at: https://knowledge4policy.ec.europa.eu/visualisation/bioeconomy-different-countries

European Commission. 2022a. REPowerEU: affordable, secure and sustainable energy for Europe. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

European Commission. 2022b. EU Bioeconomy Strategy Progress Report: European Bioeconomy policy: stocktaking and future developments: Commission staff working document. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A162%3AFIN

European Commission. Directorate-General for Research and Innovation. 2022. *EU Bioeconomy Strategy Progress Report. European Bioeconomy Policy: Stocktaking and future developments:* report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-50291-2, doi:10.2777/997651, KI-01-22-230-EN-N.

EUROSTAT. 2021. Energy import dependency, by country, 2014 and 2019. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Energy_import_dependency,_by_country,_2014_and_2019_%28%25_of_imports_in_gross_available_energy%29.png&oldid=530940

EUROSTAT. 2022a. Population change – Demographic balance and crude rates at national level ([demo_gind]). Available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_gind&lang=en

EUROSTAT. 2022b. R&D personnel and researchers in business enterprise sector by NACE Rev.2 activity and sex ([rd_p_bempoccr2]). Available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_bempoccr2&lang=en

EUROSTAT. 2022c. R&D personnel by sector of performance, professional position and sex ([rd_p_persocc]). Available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_persocc&lang=en

EUROSTAT. 2022d. CO_2 emissions from energy use up by more than 6% in 2021. Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220624-1

FACCE JPI. 2013. FACCE-JPI Evaluation framework. Framework for monitoring and evaluation of FACCE-JPI and its joint actions. Available at: https://www.faccejpi.net/en/FACCEJPI/Documents.htm

Gurria Albusac, P., Gonzalez Hermoso, H., Cazzaniga, N., Jasinevičius, G., Mubareka, S., De Laurentiis, V., Patinha Caldeira, C., Sala, S., Ronchetti, G., Guillen Garcia, J., Ronzon, T. and M`barek, R. 2022. EU Biomass Flows. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-49477-5, doi:10.2760/082220, JRC128384.

Joint Research Centre. 2022. Jobs and Wealth in the European Union Bioeconomy (Boimass producing and converting sectors)/ JRC Bioeconomics. Available at: https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html

Kulisic, B., Radic, T., Njavro, M. Strategies for post-harvesting management systems to transition to bio-hubs. *Energies* 2021, *14*.

Parisi, C. 2020. Distribution of the bio-based industry in the EU. Publications Office of the European Union, Luxembourg. ISBN 978-92-76-16408-1, doi:10.2760/745867, JRC119288.

Piotrowski S. & Dammer L. 2018. State of play of Central and Eastern Europe's bioeconomies. SCAR Bioeconomy Strategic Working Group and CASA (Common agricultural and wider bioeconomy research agenda). Available at: https://scar-europe.org/images/SCAR-Documents/Reports_outcomes_studies/BSW2_18-11-22_State-of-play-of-central-and-eastern-Europes-bioeconomies.pdf

Platt, R., Bauen, A., Reumerman, P., Geier, C., Van Ree, R., Vural Gursel, I., Garcia, L., Behrens, M., von Bothmer, P., Howes, J., Panchaksharam, Y., Vikla, K., Sartorius, V., Annevelink, B. 2021. EU Biorefinery Outlook to 2030. DG Research and Innovation of the European Commission - Studies on support to research and innovation in the area of bio-based products and services. Available at: https://www.e4tech.com/biorefinery-outlook.php

Peruško, I.V., Kovač, K., Jošić, M. 2018. Croatia in Global Value Chains. Surveys S-32, Croatian National Bank. Zagreb.

Ronzon T, Piotrowski S, Tamosiunas S, Dammer L, Carus M, M'barek R. 2020. Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU. Sustainability. 12 (11, 4507):1-13. doi.org/10.3390/su12114507

Salvador, R., Barros, M.V., Donner, M., Brito, P., Halog, A., De Francisco, A.C. 2022. How to advance regional circular bioeconomy systems? Identifying barriers, challenges, drivers, and opportunities. Sustainable Production and Consumption. Volume 32, Pages 248-269, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2022.04.025

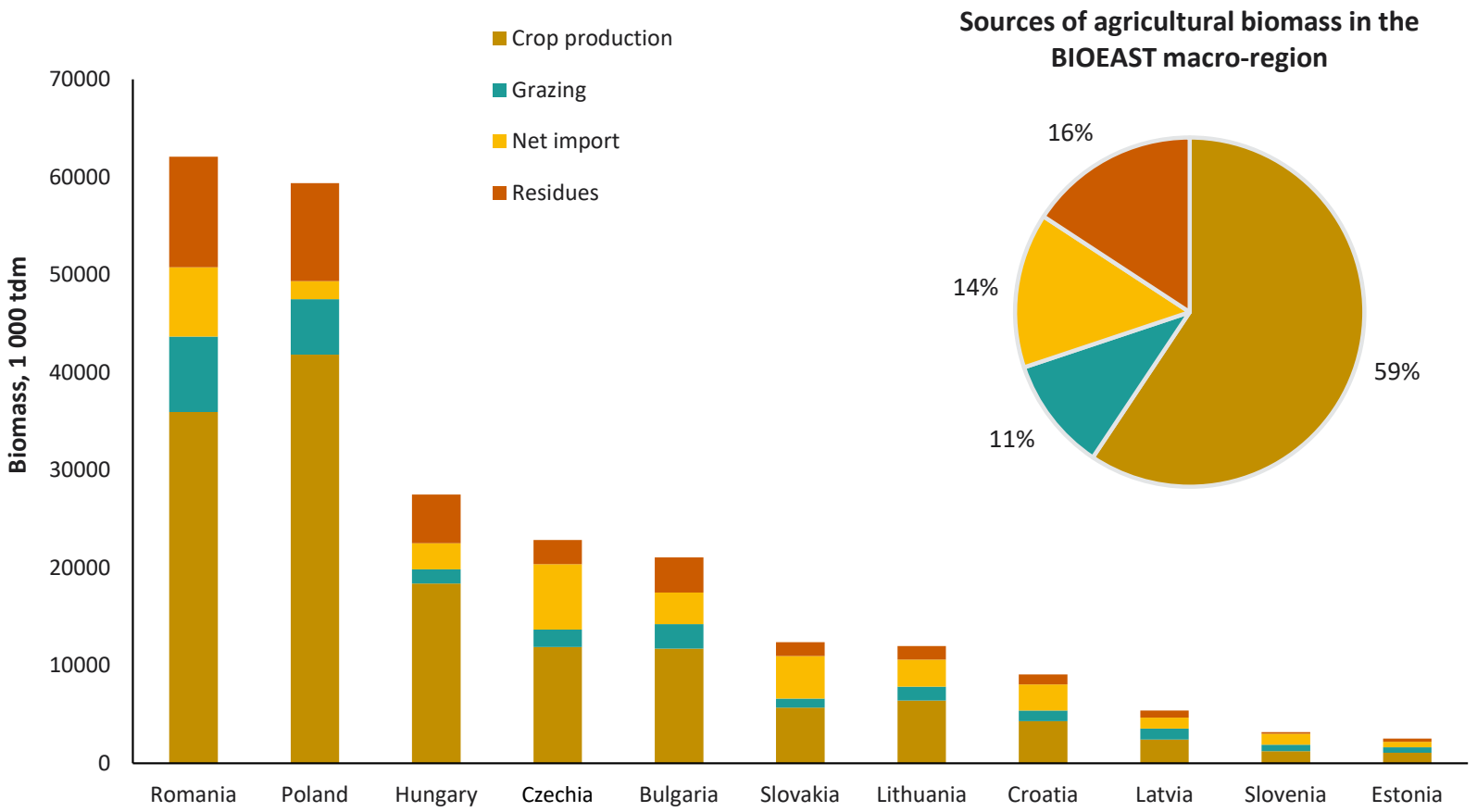
Visegrad Group. 2023. Official Statements and Communiqués https://www.visegradgroup.eu/documents/official-statements

Water JPI. 2020. Strategic Research and Innovation Agenda 2025. Available at: http://www.waterjpi.eu/mapping-agenda/strategic-research-and-innovation-agenda-sria/waterjpi_sria2025_web.pdf

ANNEXES

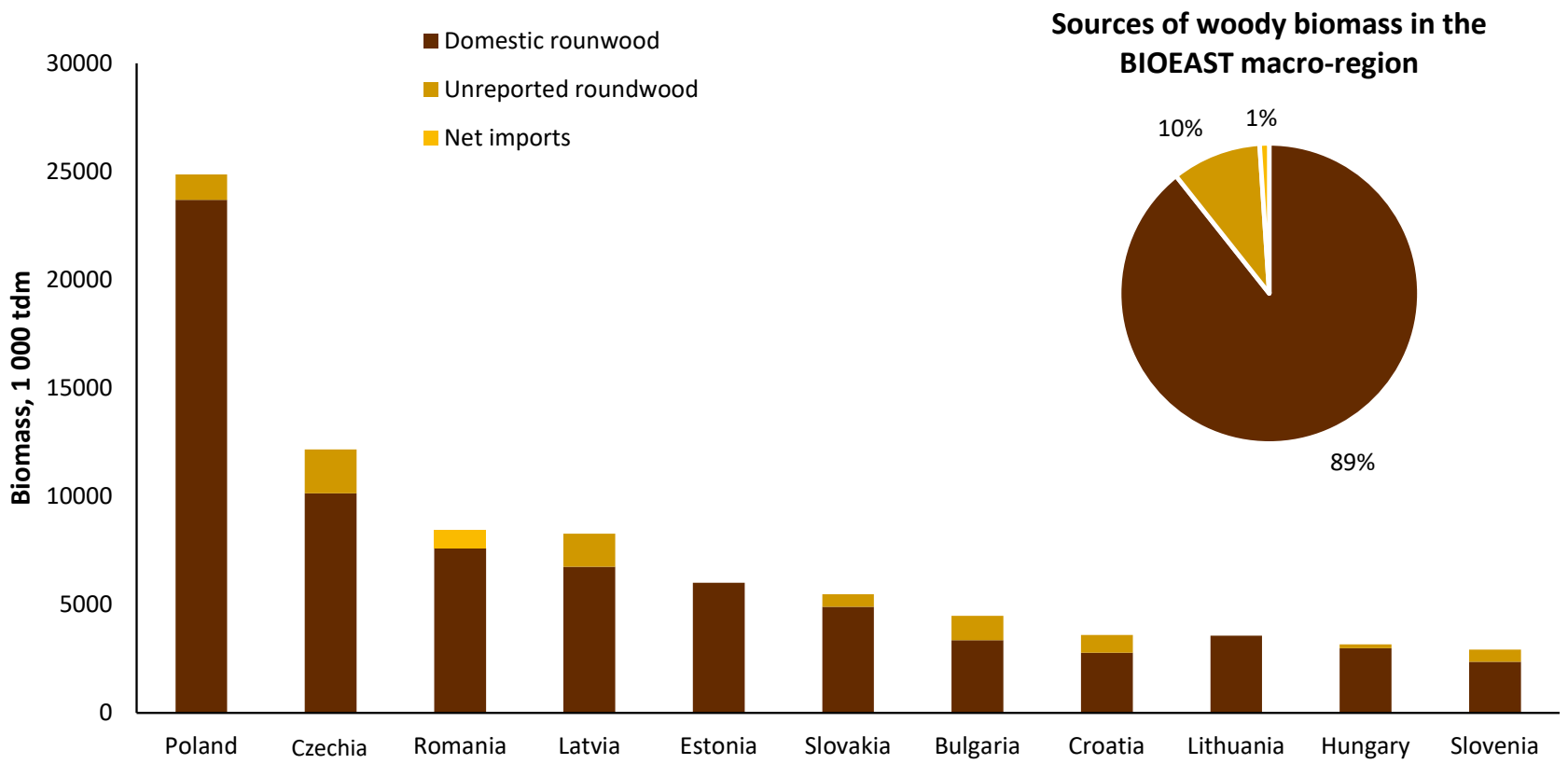
A1. BIOECONOMY IN THE BIOEAST MACRO-REGION

Figure 1 in Annex 1: **Sources of agricultural biomass in the BIOEAST macro- region (%) and in the BIOEAST countries in 2018 (1 000 tonnes of dry matter), in net trade figures**



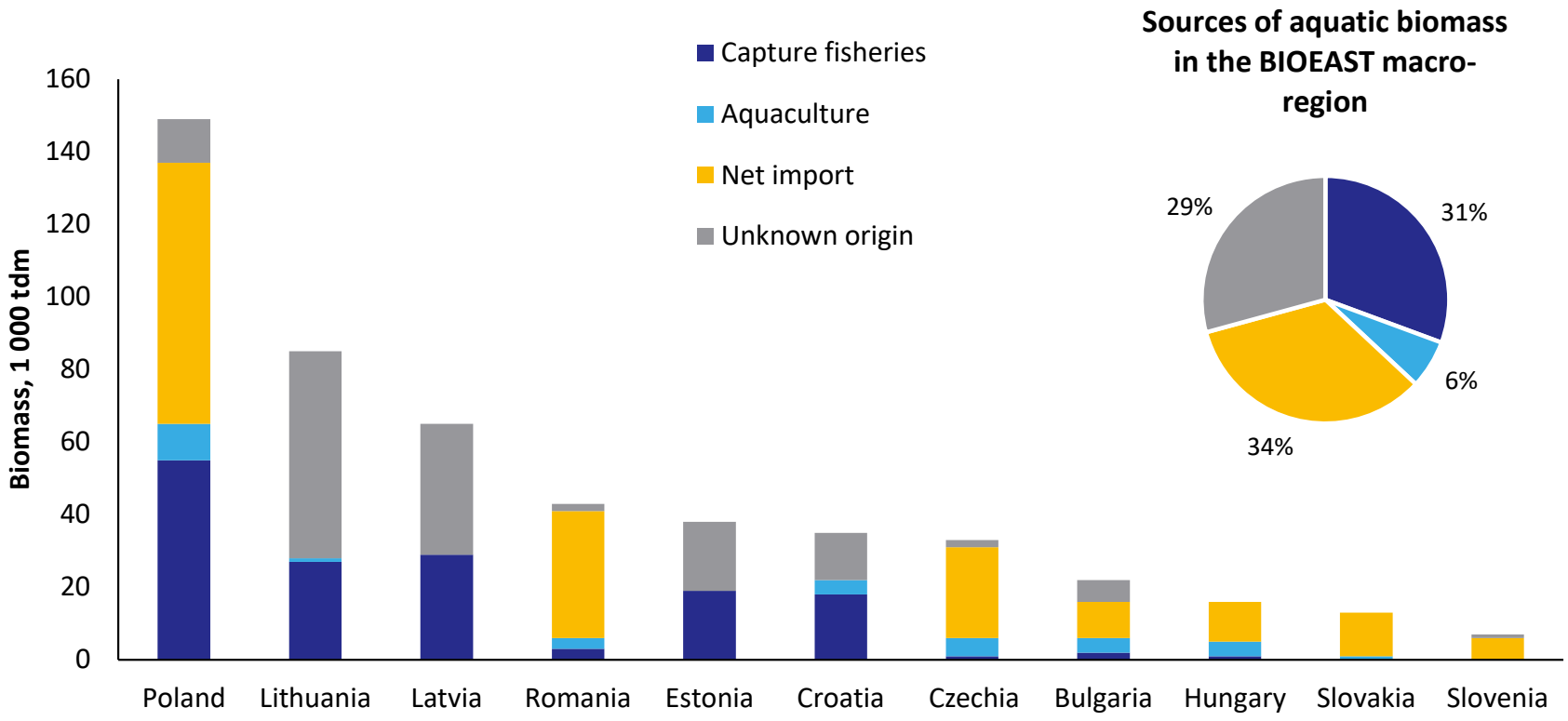
Source: DataM, 2022b.

Figure 2 in Annex 1: **Sources of woody biomass in the BIOEAST macro- region (%) and in the BIOEAST countries in 2017 (1 000 tonnes of dry matter), in net trade figures**



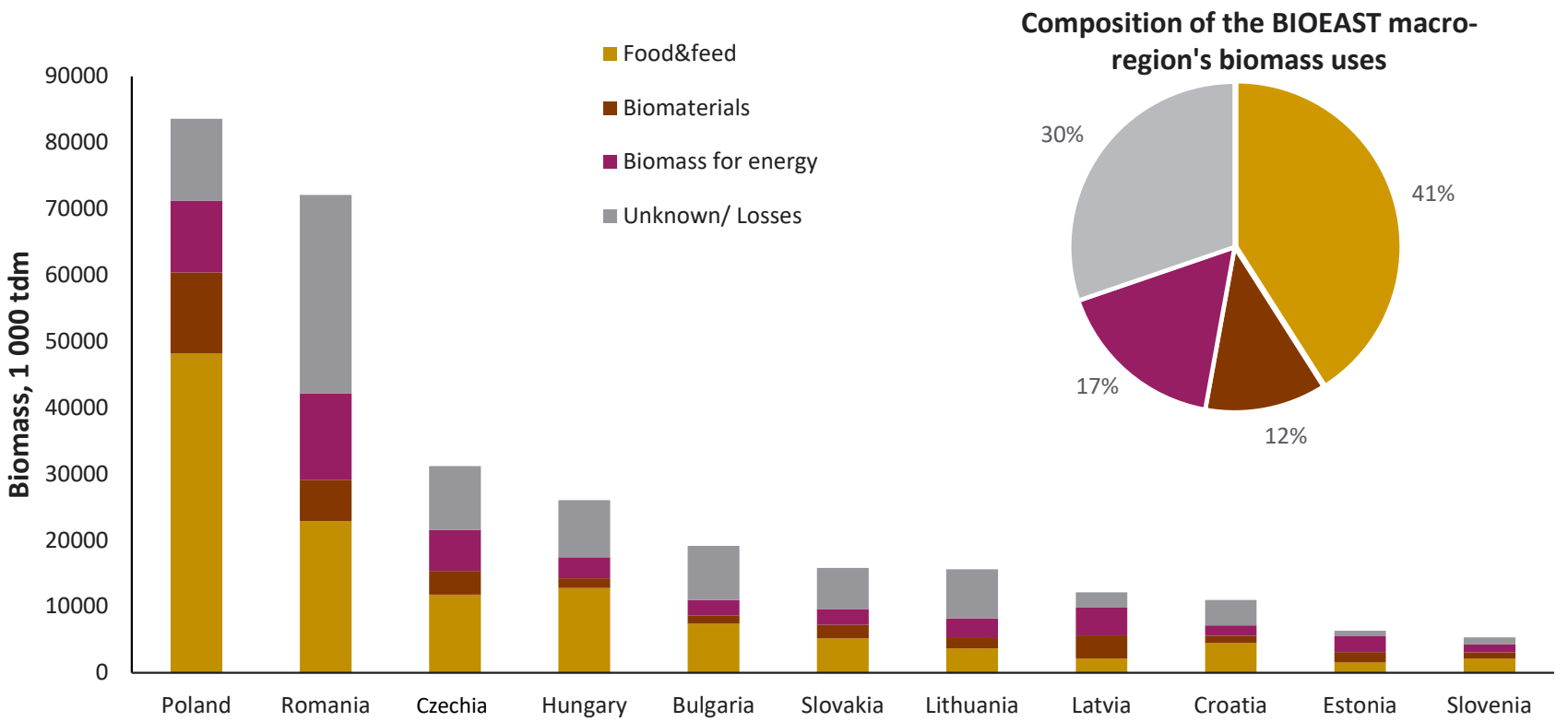
Source: DataM, 2022b.

Figure 3 in Annex 1: **Sources of aquatic-biomass in the BIOEAST macro- region (%) and in the BIOEAST countries in 2016 (1 000 tonnes of dry matter), in net trade figures**



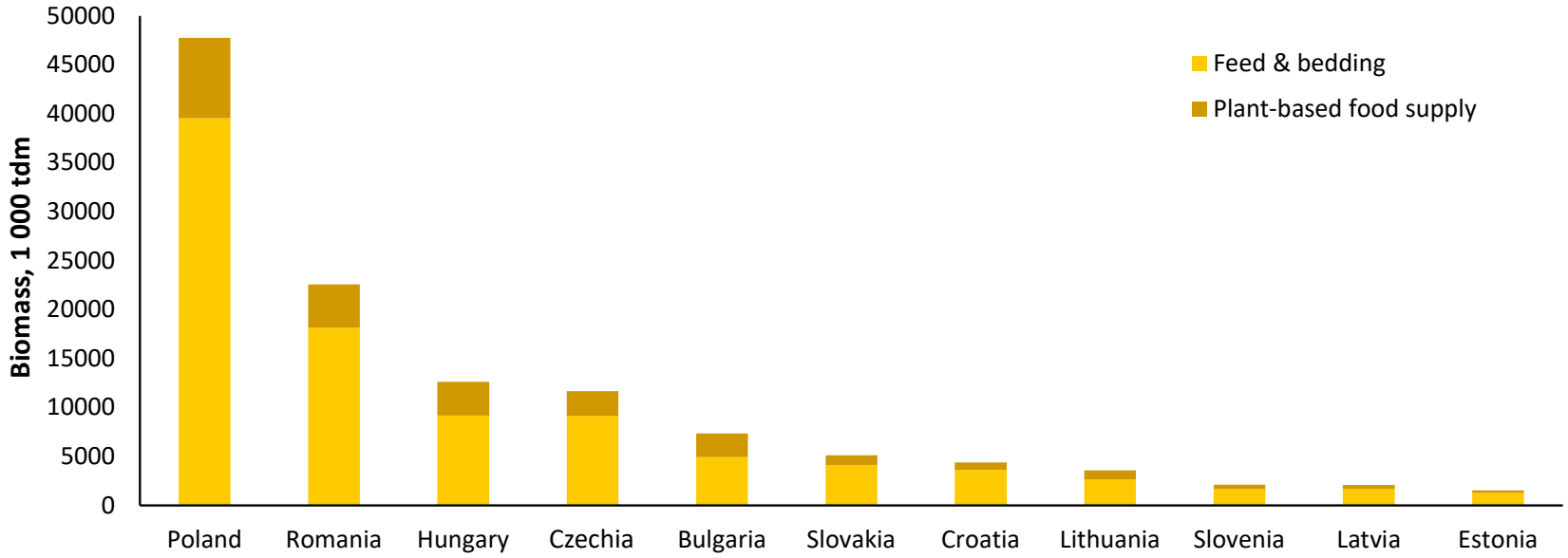
Source: DataM, 2022b.

Figure 4 in Annex 1: **Composition of the biomass uses in the BIOEAST macro-region (%) and in BIOEAST Countries in 2017 (1 000 tonnes of dry matter), in net trade figures**



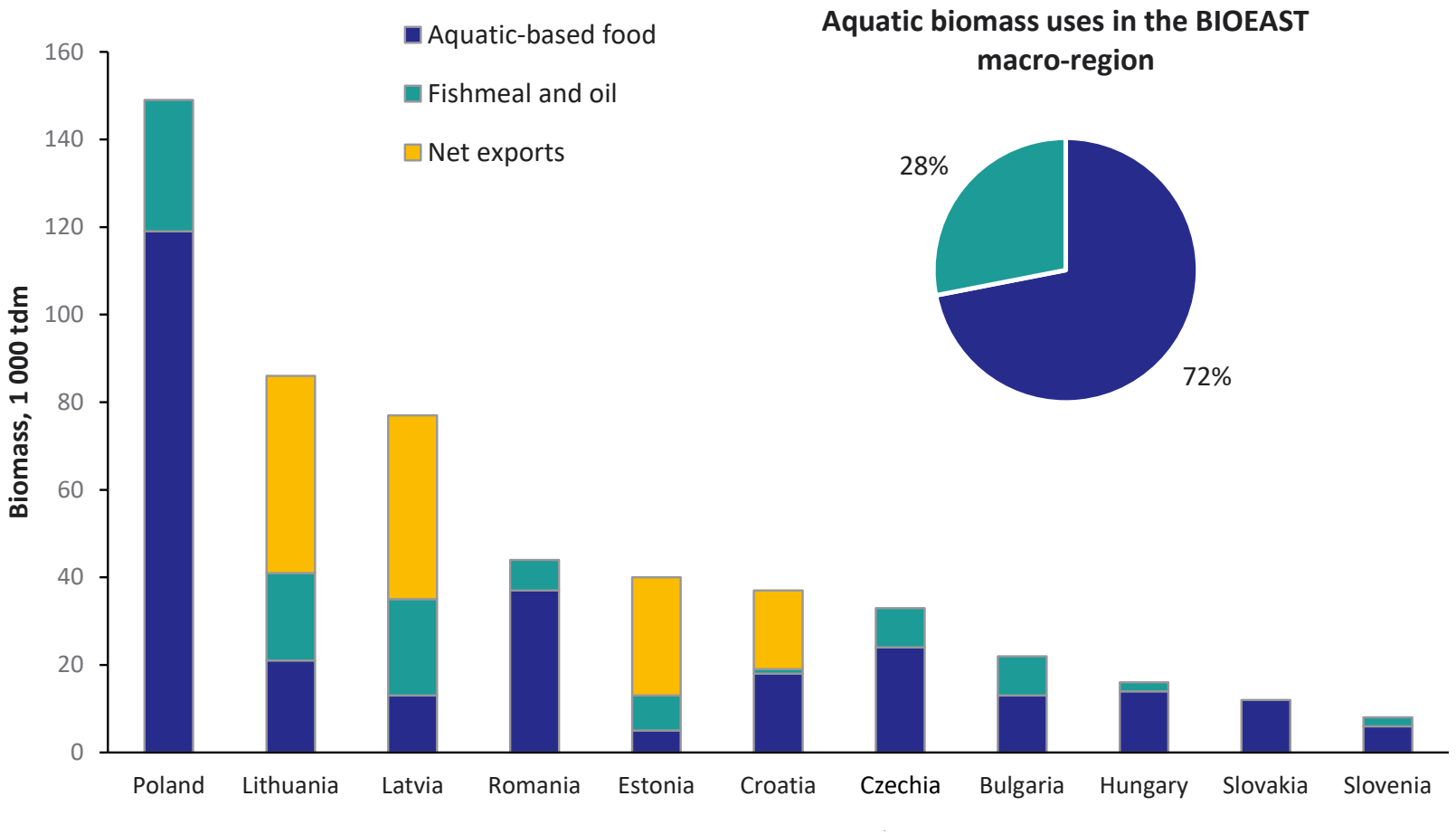
Source: DataM, 2022b.

Figure 5 in Annex 1: **Food and feed uses in the BIOEAST countries in 2018, in net trade figures, 1 000 tonnes of dry matter**



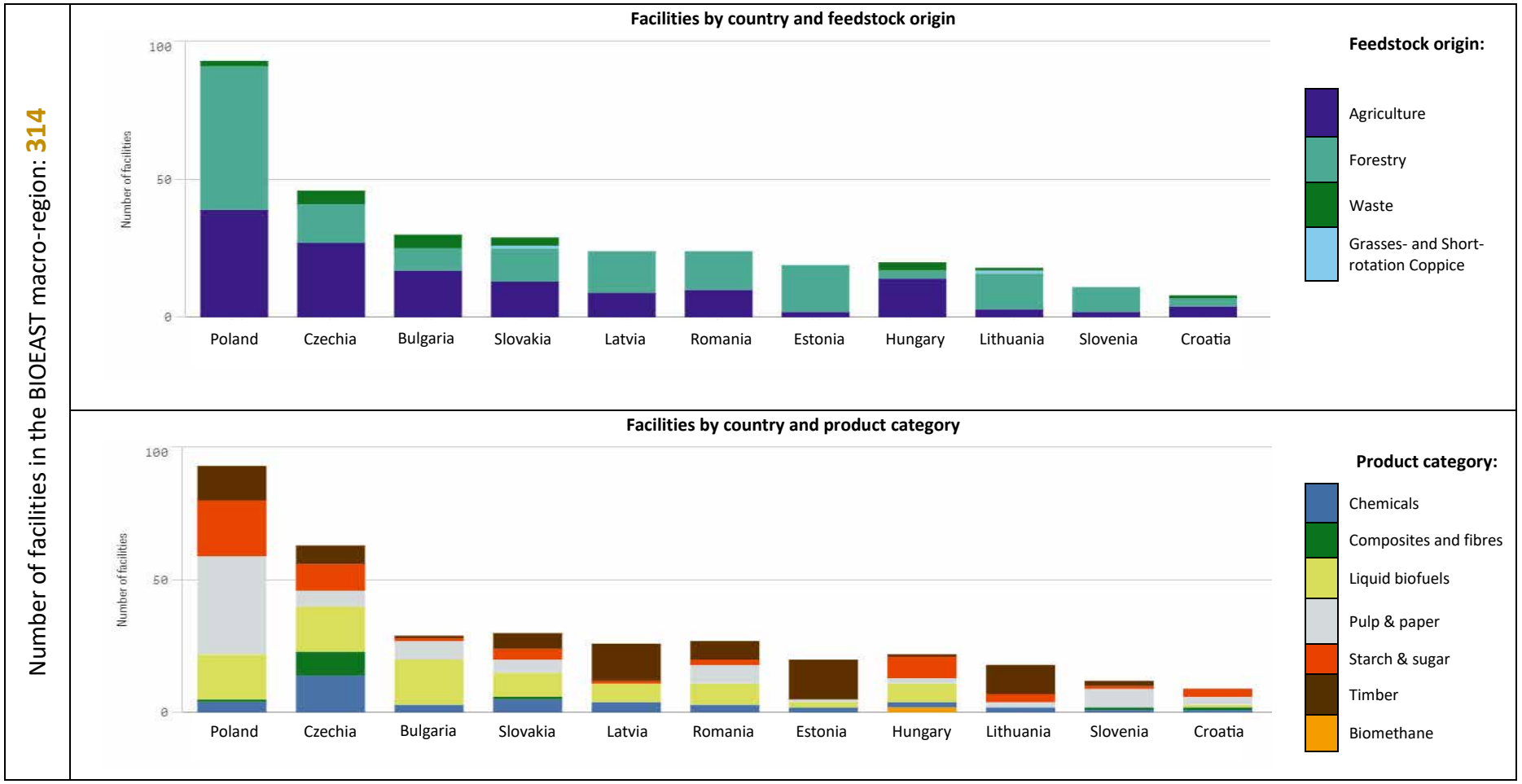
Source: DataM, 2022b.

Figure 6 in Annex 1: **Aquatic biomass uses in the BIOEAST macro-region (%) and in BIOEAST countries in 2018 (1 000 tonnes of dry matter), in net trade figures**



Source: DataM, 2022b.

Figure 7 in Annex 1: **Bio-based industry in the BIOEAST countries**



Source: DataM, 2022a.

A2. MONITORING THE PROGRESS AND IMPACT

The ambition of the BIOEAST SRIA is to be a dynamic strategy that could primarily be regarded as a process, not a static document. This calls for periodic progress monitoring and SRIA updating. In case of **BIOEAST SRIA**, **monitoring is the responsibility of the BIOEAST Board**. In the case of **thematic SRIAs**, **it is the responsibility of the TWGs**. Both the BIOEAST Board and TWGs will engage **NSPs and BAIMGs in collecting the indicator values at national level**. The BIOEAST Secretariat will ensure the periodic collection of data to monitor the progress with bioeconomy-related RDI in the BIOEAST macro-region. TWGs can initiate an **updating of the thematic SRIAs**. The BIOEAST **Board initiates the update of the BIOEAST SRIA**. In both cases, the mandate for updating comes from the BIOEAST Board. The updating of thematic SRIAS is organised by the TWG according to the SRIA framework. BIOEAST Board organises an updating of the BIOEAST SRIA following the SRIA framework.

The third building block of the BIOEAST SRIA and thematic SRIAs – 'Challenges and actions' will be updated at least **after every three** years.

MONITORING FRAMEWORK FOR THE BIOEAST SRIA

Objectives of the BIOEAST Initiative:

O 1. To develop strategies
O 2. To cooperate and develop evidence-based policies
O 3. To identify common challenges and validate common research areas
O 4. To provide the evidence base
O 5. To improve skills
O 6. To develop synergies
O 7. To increase visibility

Code of the objective	Operational objective	Criteria	Indicator	Source
	INPUT			
O 2.; O 4	**1.** BIOEAST Initiative makes impacts on national research and innovation policies as well as instruments in the BIOEAST countries	BIOEAST countries allocate national funds for joint calls	Percentage of national funds allocated to joint calls	Member State data or a questionnaire to the Member States
O 2.; O 4	**2.** BIOEAST Initiative makes impacts on national research and innovation policies as well as instruments in the BIOEAST countries	BIOEAST Initiative makes impacts on national research and innovation policies and instruments	Number of countries that indicated the BIOEAST Initiative has made an impact on the national focus of research programmes	Member State data or a questionnaire to the Member States
O 2.; O 4	**3.** BIOEAST Initiative makes impacts on national research and innovation policies as well as instruments in the BIOEAST countries	The content of research funding programmes is adapted based on the research priorities defined in the BIOEAST SRIA	Number of countries that indicated the national research funding programmes have been adapted to or aligned with the research priorities defined in the BIOEAST SRIA	Member State data or a questionnaire to the Member States
O3.; O 5.	**4.** BIOEAST Initiative mobilises researchers in all the BIOEAST countries to work together in the research areas of the BIOEAST SRIA and find solutions to the challenges defined in in the BIOEAST SRIA	Researchers working in the research areas of the BIOEAST SRIA	Number of researchers working in the research areas of the BIOEAST SRIA	BIOEAST Board reports
O 2.	**5.** Joint activities of the BIOEAST Initiative facilitate the involvement of research groups in international projects, HE Partnerships and missions	Researchers participating in international projects for the first time HE partnerships and missions, in which BIOEAST TWGs participate	Number of researchers participating in international projects for the first time. Number of HE partnerships and missions, in which BIOEAST TWGs participate	Questionnaire to researchers participating in the BIOEAST Initiative activities

Code of the objective	Operational objective	Criteria	Indicator	Source
O 2.	**6.** If necessary, the countries share their research infrastructures or develop new opportunities	Countries cooperate in sharing their infrastructures	Amount of infrastructure sharing agreements between the BIOEAST countries	Member State data or a questionnaire to the Member States
O 3.; O 5.	**7.** Development of the interdisciplinary research base in the Core Themes	Interdisciplinary research base covers interdisciplinary research areas	Number of research areas covered by the interdisciplinary research base	BIOEAST Board reports
O 2.; O 3.	**8.** Promoting cooperation between the public and private sectors	Research projects in which the private sector is involved	Number and percentage of the research projects in which the private sector is involved	Member State data or a questionnaire to the Member States
O 2.; O 3.	**9.** Promoting cooperation between the public and private sectors	Multi-stakeholder networks, clusters and demo farms are functioning	Number of joint activities launched. The number of participants in the networks and the clusters. The number of demo farms	Member State data or a questionnaire to the Member States
O 3.	**10.** Use of the BIOEAST Initiative to tackle the common challenges defined in the BIOEAST SRIA	Use of the BIOEAST Initiative to tackle common challenges	Number of joint activities launched to tackle common challenges	BIOEAST Board reports
	PROCESS			
O 2.; O 3.	**11.** Implementation of joint activities to implement the BIOEAST SRIA	BIOEAST Board launches joint activities	Quantity of joint activities launched	BIOEAST Board reports
O 3.	**12.** Addressing the research questions defined in the Strategic Research and Innovation Agenda of the BIOEAST Initiative	Joint calls launched covering the BIOEAST SRIA research issues	Percentage of the BIOEAST SRIA research issues covered in joint calls	BIOEAST Board reports
O 2.; O 4	**13.** Extent to which the BIOEAST Strategic Research and Innovation Agenda is taken up in national research programming and in EC programming	Research themes of the BIOEAST Strategic Research and Innovation Agenda covered by national research programming and EC programming	Number of transnational projects funded by national programmes	Member State data or a questionnaire to the Member States
O 2.	**14.** Joint activities of the BIOEAST Initiative facilitate the involvement of research groups in transnational projects	Researchers participating in transnational projects for the first time	Number of researchers participating in transnational projects for the first time	Questionnaire to researchers participating in the BIOEAST Initiative activities

Code of the objective	Operational objective	Criteria	Indicator	Source
	OUTCOME AND IMPACT			
O 2.; O 4	**15.** BIOEAST Initiative makes an impact on national research and innovation policies and instruments in the BIOEAST countries	BIOEAST Initiative has made impacts on national research and innovation policies and instruments	Number of the countries that indicated that the BIOEAST Initiative has had an impact on national research and innovation policies and instruments	Member State data or a questionnaire to the Member States
O 6.	**16.** BIOEAST Initiative has contributed to the attraction of regional, national, European (including Horizon Europe) and international funding (i.e., various kinds of funding actions)	Amount of funding allocated to joint calls submitted under the BIOEAST SRIA has increased each year	Percentage increase in the amount of funding allocated to joint calls submitted under the BIOEAST SRIA	Member State data or a questionnaire to the Member States
O 6.	**17.** BIOEAST Initiative has contributed to the attraction of regional, national, European (including Horizon Europe) and international funding (i.e., various kinds of funding actions)	Variety of different funding actions	Quantity of different funding actions	BIOEAST Board reports
O 6.	**18.** BIOEAST Initiative has contributed to the attraction of regional, national, European (including Horizon Europe) and international funding (i.e., various kinds of funding actions)	BIOEAST countries allocate national funding to joint calls	Percentage of national funding allocated to joint calls	Member State data or a questionnaire to the Member States
O 6.	**19.** BIOEAST Initiative has contributed to the attraction of regional, national, European (including Horizon Europe) and international funding (i.e., various kinds of funding actions)	Amount of funding allocated to joint calls by the private sector has increased	Amount of funding allocated to joint calls by the private sector as a percentage of total funding	Member State data or a questionnaire to the Member States
O 6.	**20.** BIOEAST Initiative reduces the gap between the BIOEAST countries and EU innovation leaders (Denmark, Finland, the Netherlands and Sweden)	Countries have assessed that the BIOEAST Initiative has reduced the gap between the BIOEAST countries and the EU innovation leaders	Percentage of countries that have responded that the BIOEAST Initiative has reduced the gap between the BIOEAST countries and the EU innovation leaders	Questionnaire to the Member States
O 6.	**21.** BIOEAST Initiative supports the development of sustainable circular bioeconomies in the CEE countries	BIOEAST Initiative has contributed to the development of sustainable circular bioeconomies in the CEE countries	Number of bioeconomy enterprises engaged in BIOEAST Initiative projects or joint actions	Member State data or a questionnaire to the Member States

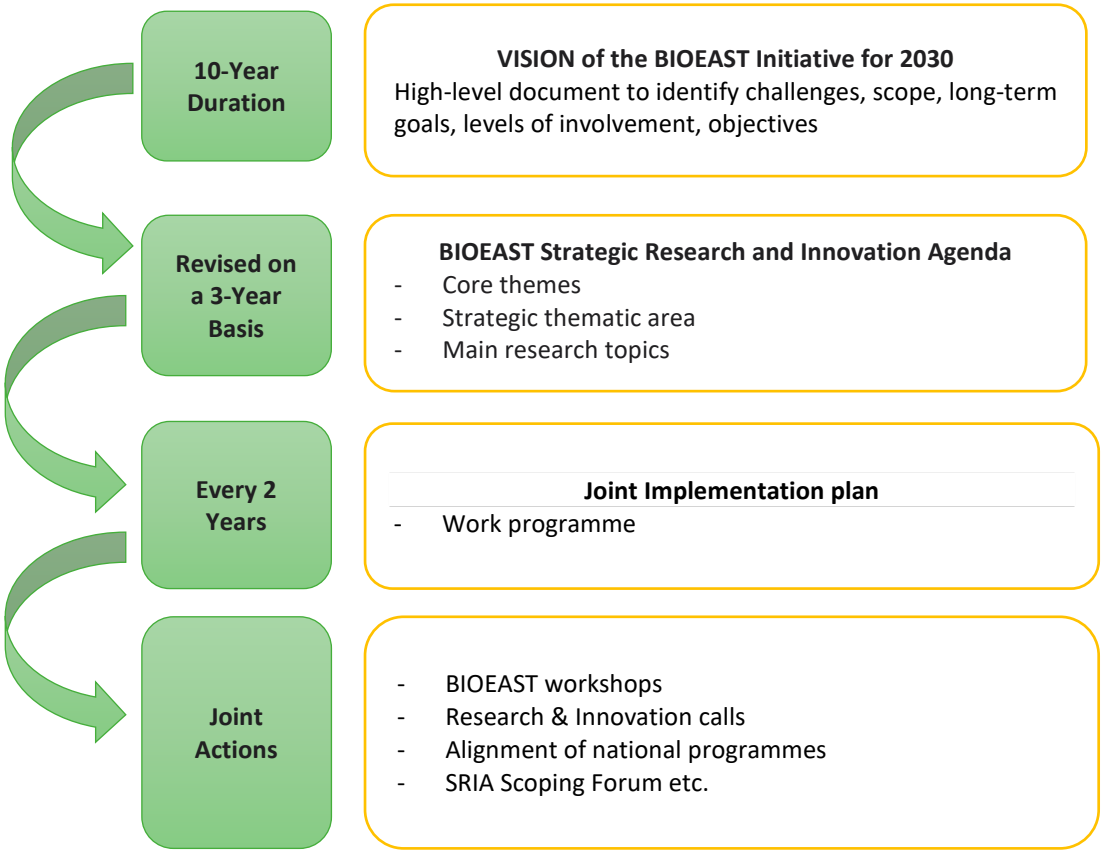
Code of the objective	Operational objective	Criteria	Indicator	Source
O 6.	**22.** BIOEAST Initiative supports the development of sustainable circular bioeconomies in the CEE countries	Stakeholders evaluate BIOEAST projects to make more efficient use of constrained resources	Stakeholders' perception of the contribution of the BIOEAST Initiative to the development of sustainable circular bioeconomies in the CEE countries	Questionnaire to the stakeholders
O 7.	**23.** Increasing research competitiveness in the BIOEAST macro-region	Demand-side recommendations developed within the BIOEAST Initiative joint activities and adopted by the stakeholders	Quantity of recommendations adopted by the stakeholders	Questionnaire to the stakeholders
O 7.	**24.** Increasing research competitiveness in the BIOEAST macro-region	Private partners have assessed that that the BIOEAST Initiative has made an impact on research competitiveness	Quantity of BIOEAST projects solutions implemented by private actors	Questionnaire to the stakeholders
O 7.	**25.** BIOEAST Initiative contributes to the knowledge base, research and innovation excellence as well as cross-sectoral cooperation in the countries participating in the BIOEAST Initiative	Stakeholders evaluate the contribution made by the BIOEAST Initiative	BIOEAST countries' perception of the contribution of the BIOEAST Initiative to the knowledge base, research and innovation excellence and cross-sectoral cooperation	Questionnaire to the stakeholders

Source: author's construction based on FACCE JPI, 2013.

THE BIOEAST SRIA UPDATING STRATEGY

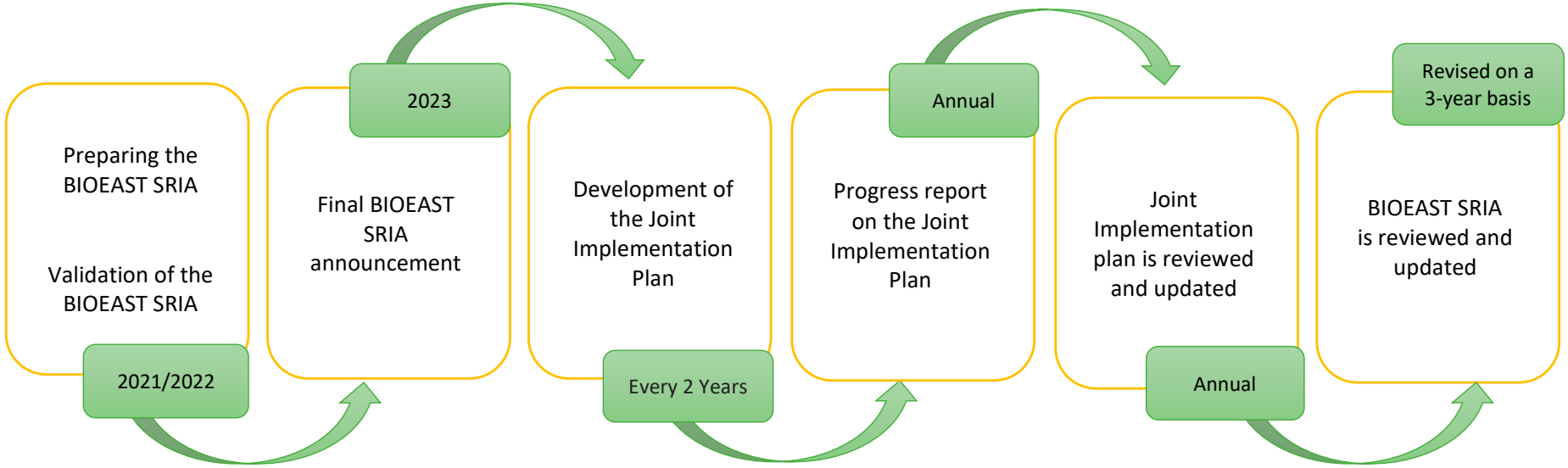
The figure illustrates the relationship between BIOEAST Vision 2030, the BIOEAST SRIA and the Joint Implementation Plan. The BIOEAST Strategic Research and Innovation Agenda will be delivered through the Joint Implementation Plan, which covers a 2-year period. The priorities will be identified and included in the Joint Implementation Plan through an iterative research process. However, the Joint Implementation Plan will be implemented through joint actions, e.g., BIOEAST workshops, Research & Innovation calls, the alignment of national programmes, the SRIA Scoping Forum, etc. The Joint Implementation plan will be regularly evaluated. The third building block of the BIOEAST SRIA and thematic SRIAs – 'Challenges and actions' will be updated at least once every three years.

Key elements of implementing the BIOEAST Initiative activities



Source: author's construction.

Key elements of updating the BIOEAST SRIA



Source: author's construction.