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BIOECO-UP

# Analysis and Mapping of Bioeconomy potentials in CEE countries (IT, SL, CR, HU, AU, PL, CZ, SK)

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| **Abstract** | Analysis collects and assesses the following data in 8 Central European countries (IT, SL, CR, HU, AU, PL, CZ, SK): biomass availability, logistic potentials, industrial initiatives, industry relevant applied research, development and inovations. It provides comparative review of bioeconomy-related strategies and policies. It discusses the demand trends for bio based products and implications for further growth of biobased sectors, including market standards and certification. |

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# Contents

EXECUTIVE SUMMARY ..... 4

1. INTRODUCTION TO BIOECONOMY ..... 8

2. METHODOLOGY OF MAPPING THE BIOECONOMY POTENTIAL ..... 9

2.1. APPROACH TO THE MAPPING: KEY ASSETS AFFECTING THE DEVELOPMENT OF BIOECONOMY ..... 10

2.2. GEOGRAPHICAL SCOPE OF THE MAPPING EXERCISE ..... 11

2.3. BIOMASS AVAILABILITY ..... 12

2.4. STRATEGIES, POLICIES ..... 15

2.5. SYNTHESIZING MAIN FINDINGS ..... 16

2.6. COMPARATIVE ANALYSIS OF NON-TANGIBLE ASSETS AND QUALITATIVE INFORMATION FROM NATIONAL REPORTS – 'TRAFFIC-LIGHT' GRAPHICAL SUMMARY AND QUALITATIVE REVIEW ..... 17

2.7. SUSTAINABLE BUSINESS MODELS AND SCENARIOS FOR CLOSING MATERIAL AND ENERGY LOOPS OF BIOMASS ..... 17

2.8. SCENARIOS FOR CLOSING MATERIAL AND ENERGY LOOPS OF BIOMASS ..... 18

2.9. LAND USE AND LAND USE INTENSITY ..... 19

3. LITERATURE, RESOURCES ..... 21

# Tables

Table 1: Sectors of bioeconomy considered in the report ..... 9

Table 2: Distribution of tasks among project members in the mapping of bioeconomy potentials..... 11

Table 3: Perspective residual biomass streams in the context of analysed countries/regions with the selection of typical/emblematic biomass streams for a more detailed value chain review (red, bolded) ..... 12

Table 4: Statistical indicators, selected for comparative analysis of bioeconomy potentials in analysed countries ..... 16

Table 5: Qualitative information from the national report on bioeconomy potentials used in the synthesis report ..... 17

Table 6: Adapted archetypes of sustainable business models, applicable tot he context of (circular) bioeconomy business models (Viira et al., 2021)..... 18

Table 7: Scenarios for closing material and energy loops of biomass ..... 19

Table 8: Total sum for key categories of land use in total land use available for biomass production in BIOECO-UP countries in 2018 (data source: EUROSTAT, 2023) ..... 20

# Figures

Figure 1: Key assets in bioeconomy (Juvančič et al., 2021, adapted from BERST, 2016) 10

Figure 2: Institutions and institutional arrangements for advancing the bioeconomy – preliminary hypotheses (Juvančič et al., 2021) 15

# Executive Summary

*Central and Eastern European countries participating in BIOECO-UP project have significant, but underutilised potential of the bioeconomy*

The overall assessment of the availability and current uses of (agricultural, forest/wood and aquatic) biomass in the six CEE countries participating in BIOECO-UP project (HR, CZ, HU, PL, SK, SI) is not favourable. The countries have a significant but sub-optimally exploited raw material potential, a handful of companies that incorporate the principles of the bioeconomy into their operations, value chains are not sufficiently established, and quality R&D work is insufficiently integrated into the business process.

*Convergence with the leading EU bioeconomy performers (represented in BIOECO-UP by AT, IT), or further widening of the gap?*

The general observation from the mapping of the bioeconomy potentials is that there is a marked difference between the CEE countries (HR, CZ, HU, PL, SK, SI) and the two benchmark countries participating in BIOECO-UP project (AT, IT) in the utilisation of (circular) bioeconomy potentials across all key indicator groups - from the structure of material flows to technological and economic parameters of productivity and investment and innovation intensity in bioeconomy industries. For quality growth and progress of a (resilient, circular, sustainable) bioeconomy, the CEE countries need to significantly strengthen their (capital, human resources, organizational) investments. Part of this effort is also systematic and focused work in terms of improved productivity of primary and conventional bioeconomy sectors, strengthened RDI and integration in cross-sectoral (and cross-border) bio-based value chains, evidence-based strategic planning, cross-sectoral and inter-institutional stakeholder networking, simultaneously with the development of supportive environment (both public and private).

*The set of indicators for mapping bioeconomy potential includes production, socio-economic and institutional criteria*

As part of the project activities, the report collects and presents indicators with which we can monitor the potential and development of the bioeconomy according to locational (environmental, production-related), economic and social (within them also institutional) criteria. Locational criteria contain data on the availability of various sources of biomass from primary agricultural production, production and consumption of agri-food biomass, primary forestry production, wood manufacturing and consumption, and aquatic biomass. The socio-economic criteria include information on business structure and economic performance (value added, employment, labour productivity) of bioeconomy sectors, investments in RDI and availability of (private) investment capital. The institutional criteria include information on the bioeconomy governance (dedicated bioeconomy strategies, instruments and measures) and on the enabling institutions for industrial innovators (such as pre-seed financing, technology parks, business accelerators).

*The various products of primary agricultural production are primarily intended for the food supply chain, where the potential for value added remains untapped.*

In line with the key problem underlying the BIOECO-UP project (unlocking the potentials for circular bioeconomy in CEE), the statistical insight into the biomass flows (in all cases, agricultural, forestry and aquatic) concentrates primarily to by-products and their valorisation. As for the agricultural production, natural endowments determine the volume and structure of primary agricultural production. As the conditions vary, the structure of agricultural biomass streams varies a lot throughout the BIOECO-UP macro region. In terms of overall volume, the largest single flow of by-products are slurry and animal manure. Its prevailing use - organic fertiliser – is indisputable, but there are untapped reserves in its prior energy use. Utilization of the bioeconomic potential of residues and by-products of plant production is appropriate to the extent that it does not jeopardize the balance of soil organic matter. However, despite taking this into

account, only 8% of the total biomass supply in the region being processed residues underlines the claim that also the potentials for valorising side streams of planned biomass are under-utilised.

*The diversity of residues in food production offers a diverse bioeconomic potential, which is difficult to assess due to data constraints.*

Residues in the food processing industry are, in material terms, biomass with an extremely diverse composition, produced in the production and processing of meat, milk, fruit, vegetables, bakery and confectionery products, as well as alcoholic and non-alcoholic beverages. A feature common to most such residues is their high water content and consequently short shelf life, so that for their effective continued use they must either be used quickly or various measures to prolong stability must be implemented. At the same time, some side streams provide a very good source of antioxidants with antibacterial and antifungal activity, and could be used to stabilize others. Determining the available amounts of residues in food processing on the basis of which their bioeconomic potential might be inferred is difficult, as similar substances can be by-products (when used) or waste (when discarded). Legally regulated monitoring is maintained only for the latter. Therefore, in order to plan economic activities that effectively exploit the bioeconomic potential of by-products in food production, the way in which data on by-products are collected should be improved, preferably in interaction between the food processing industry and interested users of these flows.

*In the case of discarded food, it makes sense to direct activities towards reducing quantities and maximum inclusion in the food cycle*

Discarded food is a significant source of waste, whose current quantities are several times higher than the amount of waste in food production. With regard to discarded food, due to its high nutritional value, ethical aspects, as well as the high energy and development expenditure of the preparation of the final food, it is advisable to develop strategies in the following order: (1) minimization of food waste; (2) inclusion of usable discarded food for human consumption; (3) use of discarded food for animal consumption and, last but not least, (4) the use of discarded food for other purposes than consumption. In the case of food waste streams inappropriate for consumption, it must also be taken into account from a technological point of view that their use is limited by a short period of stability (need for hygiene or additional stabilization) and high heterogeneity. The current use of discarded food that is not suitable for human consumption is energy (biogas) at best, and would potentially be useful for obtaining the main components in the fractionation process.

*Primary forestry production: room for improvements most prominent in lower-quality wood categories, but limitations (energy use, scale) difficult to overcome*

With respect to the natural endowments and quantities of biomass harvested, the most obvious source of biomass that would theoretically allow for an organisation of an extended bioeconomy value chain at industrial scale in a number of countries participating in BIOECO-UP project (eg. SI, CZ, SK) would be woody biomass. This holds especially for lower quality categories of wood and/or wood species. There is a number of cases of efficient valorisation of these wood categories at industrial scale through various biorefining processes (AT, CZ, SK, PL) and on niche markets (SI). There are however several limiting factors that hinder mainstreaming of such practices. The first one comes from the use of woody biomass for heating, which is the dominant way of meeting heating needs in households in rural areas. It is unrealistic to expect that the small-scale and fragmented supply of wood for energy purposes could be restructured into a system to efficiently mobilise industrially relevant quantities of wood. Another limitation comes from the structure of wood processing facilities. In cases where SMEs prevail both in the stage of primary processing of wood, as well as in processing activities based on wood raw materials (production of wood products, production of pulp and paper, extraction of wood chemicals), installation of industrial-scale ligno-cellulosic biorefinery is not a feasible option. A network of small-scale modular ligno-cellulosic biorefineries appears as a workable alternative.

*Residues from wood processing largely used for closing energy loops, significant share has more perspective alternative uses*

Given the scale of the industry (in absolute terms, AT, IT and PL are standing out, in relative terms SK, CZ and SI can be added), by-products from wood processing (waste biomass, wood, lignocellulosic fibres) are also a promising raw material for adding value in the cascade processing process, generated in the processes of extraction, processing and consumption in the forest-wood-paper chain. As for the current use of residues, by far largest proportion of residues in wood processing is used for the production of energy, most frequently to close the energy loop within the production unit or, in more advanced cases linked with co-generation (production of electrical energy), or provision of heat for other industries or district heating. Due to their technological properties, about 50% ligno-cellulosic residues derived from wood processing should be effectively available for further valorisation through biorefining. This estimate is probably on the upper end due to the high internal demand of the sector for energy.

*Agriculture, food production and wood processing contribute the largest share of employment to the bioeconomy, while agriculture is lagging in its contribution to value-added*

In the BIOECO-UP region as a whole, about 40 % of the people employed in the bioeconomy worked in agriculture, close to 20 % in food production and close to 10 % in the wood processing industry. Each other sector (with notable exception of forestry in SK) employs 3% of people or less. Compared to the sectors' contribution to the national bioeconomy value added, the contributions change significantly in the case of agriculture due to low labour productivity. As for their contribution to the bioeconomy value added, energy and green chemicals sectors stand out – both in terms of their growth in 2010-2020 period, as well as in terms of their contribution to aggregate value-added.

*The level of business consolidation (and valorisation of by-products through biorefining) rather low, with some notable exceptions*

The BIOECO-UP region has a diversified structure of companies in "conventional" processing industries of the bioeconomy (food processing, wood processing, paper mills). The level of business integration (both vertical and horizontal) varies. There National report have revealed a strong group of large-scale industrial performers. They are strongly integrated both horizontally and vertically, often integrated also into international value chains. Typical representatives are strong producer associations (IT, HU), often strongly integrated with large-scale manufacturing and international logistics (HU, PL, CZ, SK). Such cases can be seen in particular in the horticulture sectors (fruit, vegetables, wine, olives) and in primary wood processing (e.g. plywood, chip boards, pulp). In some cases (national reports for IT, AT, HU), these are incorporating biorefining practices.

The prevailing pattern of industrial organisation in conventional bioeconomy sectors in BIOECO-UP is though that small- and medium-sized operators, weakly (horizontally, vertically) coordinated. That prevents the economies of scale needed for a functioning "standard" bioeconomy concept involving companies in the same or complementary sectors with biorefining as a link. In addition, the market penetration of certain financial services, such as venture capital, is rather low due to the small market and thus limited business opportunities, which further prevents the growth of more ambitious bioeconomy clusters.

*Vigorous network of knowledge institutions, industry-related applied research (territorially and sectorally) limited*

Review of knowledge institutions distinguishes between the leading national research and higher education institutions in applied life sciences (public institutions largely prevailing), and institutions/networks that are engaged in more targeted RDI activities and whose expertise is more sector- (or product-) specific. There is a marked diversity in prevalence, as well as in the (scientific- and/or sectoral-) focus of applied research and innovation work in BIOECO-UP countries. As this type of RDI work is more often associated with concrete technological and/or organizational solutions, the private sector is more strongly engaged, often with some sort of public-private financial arrangements. In sectors marked with high RDI investment returns (e.g. chemical and pharmaceutical industry), RDI institutions are strongly associated with industry. In other sectors, these links are weaker. The industry is often reluctant to act as the sole investor in new technologies for various reasons (e.g. cost efficiency, demand-side risks, lack of financial leverage).

*Bioeconomy sectors represented in national Smart Specialisation Strategies, but not biobased value chains*

BIOECO-UP countries recognise the importance of bioeconomy sectors in their national S3 strategies. As a rule, the central role in bioeconomy-related priorities is attributed to agri-food and forest-wood value chains (with the exception of CZ, which puts emphasis also on organic waste management and sustainable transport, and HR with additional emphasis on blue bioeconomy). Relatively strongly represented is also the set of supporting enabling technologies (eg. digitalisation, advanced materials and technologies, efficient energy networks) and social innovations (eg. smart villages, eco-tourism). What is also perceivable however, is a relatively weak commitment towards comprehensive technological and social solutions, closing the material, energy and economic loops (SI as the single reported exception).

*Favourable demand trends for biobased products continue, the focus is shifting towards bulk products with low value addedenergy and fertilisers*

A number of drivers is contributing to a sustained growth of demand for renewable resources and the adoption of greener technologies. Growing consumer environmental and social awareness shapes long-trend consumer preferences, in the direction of higher demand for bio-based products. Legislation and public procurement are the policy tools that reduce the environmental impact and the ability to enlarge the market for bio-based products and services. Switching from fossil to biobased resources/technologies is also a part of corporate strategies - partly due to the growing demand and partly to increase brand recognition. In the last period, the above demand-growth factors have been accelerated by recent geopolitical developments (Covid-19 pandemic, war in Ukraine) and long-term prospects (depletion of non-renewable resources; climate change). Unlike the previously listed factors (demand for a wide array of products and services), the increase in demand is in this case largely limited to energy products and plant nutrients.

*Bioeconomy-related strategies and policies - variety of strategies and approaches*

The bioeconomy policy landscape across the partner countries is characterised by a rich tapestry of strategies and approaches. While some nations have firmly established bioeconomy frameworks, others are still in the process of shaping their bioeconomy agendas or are integrating bioeconomy actions into broader policy contexts. Moreover, partner countries have also integrated bioeconomy into broader frameworks, reflecting their unique policy priorities and strategies. This diversity underscores the multifaceted nature of the bioeconomy concept and its relevance across various policy areas. Such flexibility underscores the adaptability of bioeconomy concepts to suit a range of national contexts and development objectives. Additionally, our analysis highlights distinct patterns in institutional governance, ranging from limited inter-ministerial cooperation to robust, coordinated efforts led by one or more ministries. Understanding these variations is essential for shaping effective bioeconomy policies and fostering sustainable development in the region.

*The need for coordinated and comprehensive policy set in support of the bioeconomy*

For an efficient transition to a low-carbon and circular economy, a systemic approach needs to be adopted. It entails adapting and linking all policies – industrial, cohesion, agricultural, environmental, research and innovation, education and employment policy. Measures should be taken in all sectoral policies to tackle various challenges: (i) reduction of energy needs and emissions from production processes; (ii) reducing the consumption of primary raw materials through reuse and recycling; (iii) promoting the development and use of cost-effective, innovative low-carbon technological and non-technological solutions; (iv) encouraging the development of new materials; (v) developing new business models that include, among other things, digital transformation; and (vi) changing consumer habits in the direction of purchasing environmentally friendly products and services. A comprehensive and coordinated set from various policy domains (industrial policy, agricultural policy, environmental policy) is needed to support the transition to a circular economy and sustainable use of resources.

*Development of a favourable business environment for maximising overall (environmental, economic, social) benefits through closing biomass loops*

International research and the the experience of the two benchmarking countries in the BIOECO-UP consortium, reveal the exceptional importance of institutions involved in the critical phase in the transition from technological solutions developed at pilot level (TRL 5-6), to commercialization. This entails organizational (consulting), logistical and financial support to technology developers (most often operating as start-ups) within business incubators, start-up accelerators and venture capital funds. All these institutions are present throughout the whole BIOECO-UP region, but they are mainly of a general type, not sectoral. From the point of view of the long-term governance, which also pursues broader social goals (multiplying effects of vertically integrated biobased value chains, positive environmental effects), it would be appropriate to use public funds to better support innovative enterprises in the bioeconomy that have the potential to achieve such broader objectives.

# 1. Introduction to Bioeconomy

The bioeconomy, i.e., an economy based on producing or using biological goods and services, occupies the centre of the European Union's Green Deal, a plan to retain Europe's leading role in the wake of global challenges while transforming the economy by decarbonising it (Lovec and Juvančič, 2021). Within the EU, the countries of Central and East Europe (CEE) are often seen as lagging behind in developing their bioeconomy, thereby not harnessing the huge potential held by the bioeconomy (accounting for almost one-third of agricultural and one-quarter of forest biomass in the EU). The EU recognises this untapped potential in CEE as a specific problem and designs several support activities to reduce the development gap.

The BIOECO-UP project is one of such support activities that should contributed to the mosaic of context-related solutions. More specifically, the project is supposed to (i) develop and test procedures for transnational bioeconomy cross-sector cooperation (WP1), (ii) raise the general awareness and empower citizens to participate in making best use of the potentials of (circular) bioeconomy; (iii) verify (and adapt, where needed) measures for bioeconomy development under the current National CAP strategic plans 2023-2027 (WP3). The above listed actions are developed and tested in eight countries: Czech Republic, Hungary, Poland, Slovakia and Slovenia are coming from Central and Eastern Europe, while their regional counterparts Austria and Italy are joining the project to benchmark and to create a basis for widening and strengthening macro-regional bio-based value chains.

# 2. Methodology of mapping the Bioeconomy potential

The mapping exercise was a three-step process, consisting of:

(i) collection and interpretation of statistical evidence on resource base and performance of bioeconomy sectors;

(ii) national reports, providing a more detailed quantitative and qualitative insight into the nationally specific challenges of bioeconomy structured along the bioeconomy-related assets

(iii) synthetisation of main findings into a concise synthesis report.

In order to allow for consistency of approach with other bioeconomy-related studies in the EU, the economic sectors considered for mapping of the bioeconomy potentials is be aligned with the 'standardised' typology developed by by JRC-EC (Lasarte-López et al., 2022). Likewise to the EC-JRC typology, scoping for statistical evidence and national mapping reports focused on the non-service sectors that fall within the scope of the definition of bioeconomy according to the European bioeconomy strategy. The sectors considered are listed in the table below.

*Table 1: Sectors of bioeconomy considered in the report*

| Industry | Bioeconomy sectors |
|---|---|
| **A) Agriculture, Forestry and Fishing** | A01 – Agriculture, A02 – Forestry<br>A03 - Fishing |
| **C) Manufacturing** | C10 - Manufacture of food products<br>C11 - Manufacture of beverages<br>C12 - Manufacture of tobacco products<br>C13* - Manufacture of textiles<br>C14* - Manufacture of wearing apparel<br>C15* - Manufacture of leather and related products<br>C16*- Manufacture of wood and of products of wood and cork, except furniture;manufacture of articles of straw and plaiting materials<br>C17* - Manufacture of paper and paper products<br>C18* Printing<br>C20* - Manufacture of chemicals and chemical products<br>C21* - Manufacture of basic pharmaceutical products and pharmaceutical preparations<br>C22* - Manufacture of rubber and plastic products<br>C31* - Manufacture of furniture |
| **D) Electricity, gas, steam and air conditioning** | D35* - electricity and heat (from biomass) |
| **Others** | F41* Construction<br>E38*, E39* Waste management |

Sectors A01, A02, A03, C10, C11 and C12 are considered fully bio-based, meaning these sectors are considered to engage exclusively in production and valorisation of biomass. The remaining sectors (C13, C14, C15, C16, C17, C20, C21, C22, C31) are considered "hybrid sectors" in the sense that the products they produce contain biomass and fossil-, mineral-based or synthetic content. This report is focusing on the 'bio-based' segment of these sectors, same holds for sectors, such as electricity generated from biomass.

Sectors construction and waste management also fall under the EU definition of the Bioeconomy. Although the quantification of their bio-based share is work-in-progress and can thus not be retrieved in the JRC database, these three sectors have been taken into account in the national mapping reports.

## 2.1. Approach to the mapping: key assets affecting the development of bioeconomy

In addressing key assets in the transition to the bioeconomy and their interactions, we are adopting the approach originally developed for analysing bioclusters in the EU (BERST, 2015) and in an extended version for analysing the bioeconomy potentials in BIOEAST countries (Juvančič et al., 2021). In the visual presentation of key assets affecting the pace and direction of the transition to the bioeconomy (Figure 1), the core consists of the **elements of quadruple helix of innovation**:

**Entrepreneurs**. The presence of entrepreneurial culture plays a pivotal role in driving clusters towards successful development. Clusters usually leverage the presence and active participation of various individuals with an entrepreneurial spirit who are flexible, risk-takers and willing to try new ideas. The level of entrepreneurial culture can therefore be seen as a critical success factor, whereas low levels of entrepreneurship would be a cause for concern (PWC, 2011).

**Policymakers**. Political leaders who are willing to support the development of the bioeconomy, providing governance, institutional structures and financial support.

**Knowledge institutions**. Organisations that provide technical know-how and innovation for the development of bio-products.

**Consumers**. Some authors (e.g. Falcone and Imbert, 2018) argue for a stronger inclusion of consumers' perceptions and preferences for bio-based products. This would allow consumers, where properly communicated, to make more informed and socially aware purchasing choices.

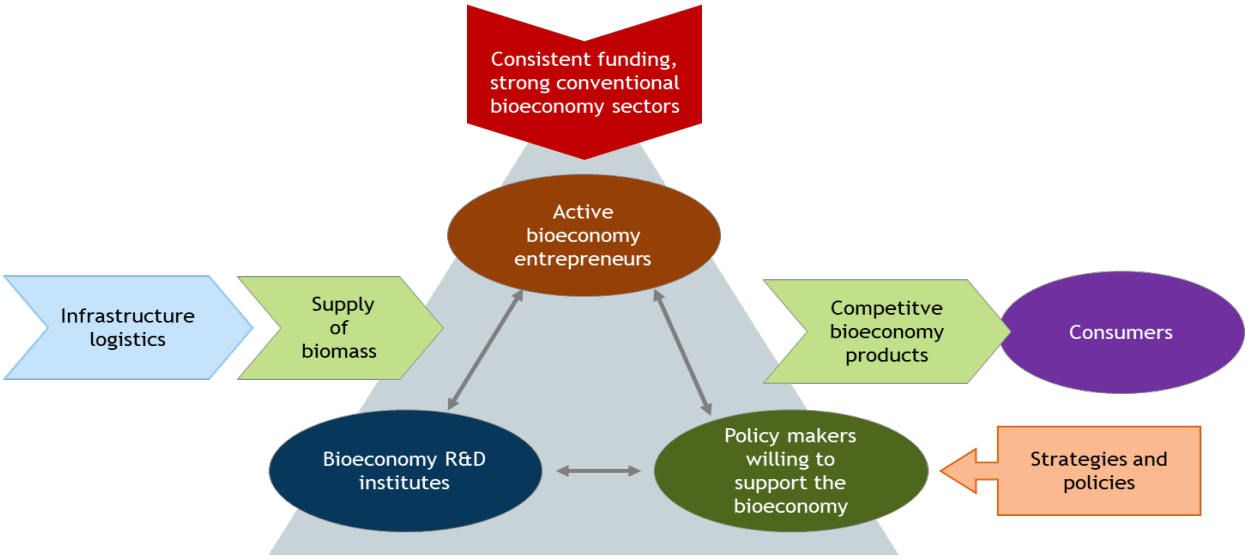


*Figure 1: Key assets in bioeconomy (Juvančič et al., 2021, adapted from BERST, 2016)*

The generic core is enhanced by assets that are case-specific for bioeconomy. The following groups of assets play key roles:

**Biomass supply:** A substantial part of the bioeconomy builds on biomass as a resource base. Ideally, biomass production should take ecological, social and health aspects into consideration and be internationally competitive. Through the development of new technologies and biotechnological processes, biomass is used for food, feed and materials as well as for energy purposes (Staffas et al., 2013). However, competing claims on the use of biomass (particularly between material and energy use) are a challenging issue in the process of unlocking the bioeconomy potential. With respect to this, (Lewandowski, 2015) underlines the importance of participatory and bottom-up approaches in the process of sustainably mobilizing the biomass potential.

**Efficiency of Infrastructure/logistics:** Consistent, timely and cost-effective provision of biomass resources is critical. The analysis of case studies and best practices (e.g. BERST, 2015) underlines the importance of the efficient collection and distribution of biomass streams (both locally sourced and imported) from the point of origin (collection network in the case of primary production, or processing sites in the case of side streams) to the locations of intermediate (e.g. biorefinery) and final transformation (e.g. bio-based materials and products, energy).

**Competitive bioeconomy products:** This asset consists of a wide range of commercially viable bio-based products, ideally produced along the cascading use of biomass. The logical sequence of production follows the path from low quantity / high added value (e.g. biopharmaceuticals, fine chemicals, functional food ingredients) to conventional uses (such as food, paper&pulp, wood products) and, following the biorefining process to bio-based products (e.g. green chemicals, bioplastics), to bulky outputs with lower added value (e.g. biofuels, electricity and heat).

**Presence of strong 'conventional' bioeconomy sectors:** the presence of entrepreneurs and entrepreneurial culture has been listed among the other key assets in all the cluster development stages. The analysis of case studies and best practices (BERST, 2015) reveals the importance of networking and interaction among enterprises from set-up to maturity stages. However, where the cascading use of biomass and development of bio-based solutions was mostly driven by the industrial demand for innovative products or components (chemicals & polymers, construction etc.), the presence and active participation of large industrial actors from 'conventional' bioeconomy sectors proved more important.

**Funding:** consistent funding both from public and private sources, new funding resources and attractive funding mechanisms for entrepreneurs and investors.

**Strategies and policies:** legislative and policy-framework conditions affecting the introduction of products made from biomass, including measures relating standards, labels, certification and public procurement.

## 2.2. Geographical scope of the mapping exercise

Responsibilities of project partners in carrying out A1.1 are outlined in Table 2 below. The central feature in the mapping of the bioeconomy potentials are National reports, prepared by project partners.

*Table 2: Distribution of tasks among project members in the mapping of bioeconomy potentials*

| Country | Partner | Task |
|---|---|---|
| CZ | CZU<br>ART | Collecting data and preparing national report for CZ |
| HR | HPK | Collecting data and preparing national report for CRO |
| HU | HUMA<br>BZN | Collecting data and preparing national report for HU; co-leading A1.1 |
| PL | IUNG | Collecting data and preparing national report for PL |
| SK | BEC<br>ART | Collecting data and preparing national report for SK |
| SI* | UL* | Preparation of templates for national reports; collecting statistical evidence for comparative analysis; Collecting data and preparing national report for SI, preparation of D1.1.1; leading A1.1 |
| AT | BAB | Collecting data and preparing national report for AT |
| IT | UNIBO | Collecting data and preparing national report for IT; co-leading A1.1 |

The national reports have been prepared along the unified template and following the guidelines, prepared by A1.1 Lead (UL). We were first drawing the attention to the geographical scope of the exercise. For

participating countries which are a part of the BIOEAST initiative, national reports and the whole mapping exercise has been carried out at the national level. Slightly different approach was taken in the case of one of the participating 'benchmarking' countries, Italy. Taken into account the size and geographical position of Italy, and with regard to the thematic focus of the project (transnational bio-based industry value chains), we limited the mapping exercise to the North-East and North-Est NUTS-1 regions, which are regions adjacent to the 'macro-region' consisting of the countries participating in the project.

## 2.3. Biomass availability

In description of the biomass availability, the national reports were instructed to limit themselves to the description of the residual biomass streams, which are currently employed, or potentially available for further valorisation. The starting point for analysing biomass availability and biomass flows is the JRC – Biomass uses and flows database (EC, 2023). More than just collection and graphical interpretation of these data, the evidence base on biomass availability and flows was used to make informed judgements about the current use of the listed biomass streams and suggestions for possible improvements. Where deemed relevant, the national teams were requested to describe possible alternative uses of selected biomass streams and to outline the critical factors to render these alternatives feasible.

In order to keep the focus, the national reports were requested to highlight only a limited number of most perspective residual biomass streams. In the quantification, description of current use and comments on possible alternative uses, the national teams were requested to highlight:

- up to 5 categories of residual biomass from agriculture
- up to 5 categories of residual biomass from processing and consumption of agri-food products
- up to 3 categories of residual biomass from primary forestry production
- up to 3 categories of residual biomass from processing and consumption of forestry-wood biomass
- at least one category of residual biomass from aquatic systems (fisheries, aquaculture, algae).

For each of the above listed groups of biomass, a more detailed value chain was conducted for at least one biomass stream. Based on the review of available data on biomass flows, and expertise of the national teams on the current use and potentials for further valorisation, the following categories of residual biomass were taken into account in the national reports (Table 3):

*Table 3: Perspective residual biomass streams in the context of analysed countries/regions with the selection of typical/emblematic biomass streams for a more detailed value chain review (red, bolded)*

| | Perspective residual biomass streams from… | | | | |
|---|---|---|---|---|---|
| | **Primary agricultural production** | **Food processing and consumption** | **Primary forestry production** | **Processing of wood biomass** | **Aquatic biomass** |
| **Austria** | **Straw**, husks, bran (grain harvesting residuals)<br>Manure and slurry surplus<br>Sugarbeet leaves<br>Potato harvest residuals | Whey (dairy by-products)<br>Slaughter by-products<br>Beer brewing residuals<br>Starch production residuals<br>**Food waste** | **Felling & calamity wood**<br>**Residues of primary processing (bark, knots)**<br>Residues from logging | Residues from pulp and paper industry<br>Residues from wood panel production | **Aquaponics** |
| **Czech Republic** | **Straw** (grain harvesting residuals)<br>**Manure and slurry surplus**<br>Non-harvested and discarded crops (fruit & veg) | Whey (dairy by-products)<br>Slaughter by-products<br>Residues in beverage production (e.g. | **Wood of inferior quality** (e.g. pulp and chemical industry, wood panels, wood fuel) | Residues of wood processing (cutter chips, bark, lump wood residues)<br>Papermill sludge (primary, secondary, deinking) | Aquaculture by-products<br>Algae biomas, aquatic plant residues |

| | | | | | |
|---|---|---|---|---|---|
| | By-products in animal production (e.g. wool) | pomace, yeast sediments)<br>Residues of milling, bakery and confectionary<br>Residues of fruit&veg processing (e.g. pomace, skins) | Residues from logging (branches etc.)<br>Residues of primary processing (sawdust, tree bark, wood knots) | | |
| | **Primary agricultural production** | **Food processing and consumption** | **Primary forestry production** | **Processing of wood biomass** | **Aquatic biomass** |
| **Croatia** | Crop residuals (cereals, oil-crops)<br>Horticulture residuals<br>Fruit&veg by-products<br>Manure and slurry surplus<br>Biomass of fruit and viticulture production (pruning)<br>Flowers and medicinal plants | Residues from fruit&veg processing<br>Plant oil production (cake, pomace)<br>Dairy by-products<br>Meat processing by-products<br>Production of wine and grape distillates (skin, seeds, pomace) | Fast growing tree species<br>Wood chips<br>Sawdust<br>Bark | Paper industry by-products<br>Furniture industry by-products | Mariculture - fish residues (pea, roe, bones, offal) |
| **Italy (NW&NE NUTS-1)** | Harvesting residues (straw etc)<br>Non-harvested or discarded crops (fruit&vegetables)<br>**Horticulture residuals (green cut, by-products, crop residues)**<br>Manure and slurry surplus | **Residues from canning industry (fruit&veg)**<br>Residues from the pressing of olives<br>Production of wine and grape distillates (skin, seeds, pomace)<br>Residues deriving from durum wheat processing<br>Residues from rice industry | **Primary forest residues (branches, stumps and tree-tops)**<br>Wood from Public green maintenance<br>Residues from primary wood processing (sawdust, bark, shavings, trimmings, trimmings) | **Secondary forest residues** (cutter chips, bark, slabs, lump wood residues)<br>Residues from secondary wood processing (sawdust, shavings, trimmings and other)<br>Residues from the paper industry (barks, trimmings, pulper)<br>Recycled wood | Residues of sea fisheries<br>Residues from aquaculture |
| **Slovakia** | Manure and slurry surplus<br>**Harvesting residues (straw etc.)**<br>Plant residues in horticulture (e.g. stems, leaves) By-products in animal production | Residues from slaughter&meat processing<br>Dairy processing byproducts<br>Residues in the production of beverages<br>Residues of fruit and vegetable processing<br>**Food waste** | **Residues from logging (branches, woodchips)**<br>Wood of inferior quality<br>**Residues of primary processing** | **Residues in paper industry**<br>Residues in furniture industry | Residues from freshwater aquaculture |

| | | | | | |
|---|---|---|---|---|---|
| **Slovenia** | **Manure and slurry surplus**<br>Non-harvested and/or discarded crops (fruit&veg)<br>Straw, husks, bran (grain harvesting residuals)<br>**Plant residues in horticulture** (eg. pruning residues)<br>Secondary products in animal production | Dairy (whey, buttermilk)<br>**Residues from slaughter&meat processing**<br>**Residues in the production of beverages**<br>(eg. pomace, yeast sediments)<br>Residues of milling industry, bakery, confectionery<br>Residues of fruit and vegetable processing (e.g. fruit pomace, skins)<br>Food waste | **Wood of inferior quality**<br>Residues from logging (branches etc.)<br>**Residues of primary processing (sawdust, tree bark, wood knots)** | Residues from secondary wood processing (sawdust, shavings, trimmings and other)<br>Residues from paper industry (papermill sludge - primary, secondary, deinking; paper powder)<br>Discarded wood | **Residues from processing and canning of fish**<br>Residues from freshwater aquaculture |
| | **Primary agricultural production** | **Food processing and consumption** | **Primary forestry production** | **Processing of wood biomass** | **Aquatic biomass** |
| **Hungary** | Manure and slurry surplus<br>Non-harvested and/or discarded crops (fruit&veg)<br>Residues of vegetables, oilseeds, roots<br>Harvesting residues (e.g. straw)<br>Plant residues in horticulture (e.g. stems, leaves, pruning residues) | Side products in the processing and production of meat products<br>Dairy production (e.g. whey, buttermilk)<br>Residues in the production of beverages (e.g. pomace, yeast sediments)<br>Residues of milling industry, bakery and confectionary<br>Residues of fruit and vegetable processing (e.g. fruit pomace, skins)<br>Food waste | Wood of inferior quality (e.g. pulp and chemical industry, wood panels, wood fuel)<br>Residues from logging (branches etc.)<br>Residues of primary processing (sawdust, tree bark, wood knots) | Residues from secondary wood processing (sawdust, shavings, trimmings and other)<br>Residues from paper industry (papermill sludge - primary, secondary, deinking; paper powder)<br>Discarded wood | Residues from freshwater aquaculture |
| **Poland** | Crop residuals (straw, corn cobs, sugarbeet leaves)<br>Manure and slurry surplus<br>Horticulture residuals<br>Fruit&veg by-products | Side products in the processing and production of meat products<br>Residues in the production of beverages (e.g. pomace, yeast sediments)<br>Residues of milling industry, bakery and confectionary | Wood of inferior quality (e.g. woodchips from primary production and manufacturing) | Residues from secondary wood processing (sawdust, shavings, trimmings and other)<br>Discarded wood (e.g. Wood-based panels) | Residues from freshwater aquaculture (e.g. from carp and trout production) |

## 2.4. Strategies, policies

This section of the national reports starts by contemplating the status of bioeconomy in national (regional) development strategies. National reports for countries with accepted dedicated bioeconomy strategies (IT, AT) are able to provide brief information of their contents, priorities, and relations with public policies. Similar holds for the countries where the national bioeconomy strategies are currently under development (CR, HU, SK, CZ, PL). For countries with no dedicated bioeconomy strategies (SI), national reports provide information, whether and to what extent bioeconomy-related issues are integrated into the mainstream programming documents (eg. National CAP Strategic Plan, ESIF Operational Programmes).

Bioeconomy is a horizontal concept that is integrated into governance structures in different ways. Although capturing of relations between governmental institutions is rather complex and it is somewhat hard to distinguish unequivocally between governance types. The BIOEASTsUP project carried out an institutional mapping exercise and established a typology of four governance types (Juvančič et al., 2021). The first governance arrangement group (Type 1 and 2) includes countries where the organization of bioeconomy issues and delivery of its policy is generally centralized and coordinated by one lead ministry. In governance type 2, this is usually a ministry that is directly linked to the 'traditional' bioeconomy sector, e.g. agri-food and/or forestry-wood sectors. Governance Type 1 has one leading ministry, whose portfolio is multi-sectoral (eg. Ministries of technology, economic affairs, etc.). 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. Type 4 has a similar decentralized ministerial distribution. However, more stakeholders, with stronger linkages, are involved in the process of bioeconomy policy delivery.

*More stakeholder involvement, types of actors, interactions* →

*Distribution of power / sectors considered* ↓

| | |
|---|---|
| Type1:<br><br>Centralised, one lead ministry | Type2:<br>One lead ministry, designed by distinct axis of bioeconomy (eg agriculture/food; forestry – wood chain) |
| Type3:<br>Divided, 2 or more lead ministries/agencies, ‚traditional' and ‚novel' sectors of bioeconomy considered | Type4:<br><br>Strongly devolved multiple actors |

*Figure 2: Institutions and institutional arrangements for advancing the bioeconomy - preliminary hypotheses (Juvančič et al., 2021)*

The national reports were requested to check whether the described governance models correctly represent the actual situation in the BIOEAST countries, whereas AT and IT were invited to consider which of the four governance models fits best their situation.

The way how bioeconomy is integrated into Smart specialization strategies is a good indicator of the significance, and potentials of bioeconomy sectors, as commonly perceived by key national actors of the innovation helix (industry, research, government). For this reason, the national reports extended the mapping exercise with the overview of the latest available information on the Smart Specialisation Strategy (S3) priorities.

## 2.5. Synthesizing main findings

While the comparative analysis of bioeconomy potentials in the analysed countries is structured along the bioeconomy-related assets and (Figure 1), each of the asset-related chapters begins with a review of relevant statistical indicators from verified sources. The scope of available data differs from one chapter to another. Generally speaking, meaningful comparative analysis, based on standardised statistical indicators is possible in four chapters: (i) Biomass availability, (ii) Infrastructure and logistics, (iii) Industrial initiatives, and (iv) Research, development and innovation. The indicators are presented and briefly described in Table 4 below.

*Table 4: Statistical indicators, selected for comparative analysis of bioeconomy potentials in analysed countries*

| Bioeconomy-related asset | Topic | Indicator | Source of data |
|---|---|---|---|
| **Biomass availability** | Land use | Land use by categories | Eurostat (2023) |
| | Agricultural biomass | (Plant-based) biomass from agriculture | European Commission (2023a) |
| | | Agricultural biomass uses and losses | |
| | | Quantities and structure of imports and exports of agricultural biomass | |
| | Forestry biomass | Biomass from forestry | |
| | | Woody biomass by categories | |
| | | Quantities and structure of imports and exports of woody biomass | |
| | Aquatic biomass | Structure of fishery & aquaculture biomass | |
| **Infrastructure - logistics** | Biomass transported | Freight volume of biomass - agriculture | Eurostat (2023) |
| | | Freight volume of biomass - forestry | |
| | Infrastructure – potentials and capacities | Road freight transport density | |
| | | Rail freight transport density | |
| | | Inland waterways transport density | |
| **Industrial initiatives** | structure & performance of bioeconomy sectors | Structure of value added by the bioeconomy sectors (%) | European Commission (2023a) |
| | Employment in bioeconomy | Structure of value added by the bioeconomy sectors (%) | |
| | Labour productivity in bioeconomy sectors | Labour productivity by sectors (000 EUR) | |
| | Investment intensity | Investment share of GDP by institutional sectors | Eurostat (2023) |
| **Research and Innovation** | RDI | R&D intensity in BIOECO-UP countries in the business enterprise sector | Eurostat (2023) |
| | | R&D personnel in BIOECO-UP countries in business enterprise sector | |
| | Entrepreneurial activity | SME birth rate | |

Statistical indicators outlined above are obtained from two publicly available sources; (i) Eurostat database clearly structured by themes (Eurostat, 2023), and (ii) European Commission´s Data-Modelling platform of

resource economics (European Commission, 2023). Where available, review of statistical indicators provides the starting point in the comparative review of bioeconomy-related assets in the analysed countries. In order to ensure consistency of this task, collection, presentation and interpretation of statistical indicators was carried out centrally by the research team from the leading partner for this action, UL.

## 2.6. Comparative analysis of non-tangible assets and qualitative information from national reports

The core information for mapping of bioeconomy potentials in the participating countries comes from the national reports. The national reports provide in-depth quantitative information for their most perspective residual biomass streams and qualitative information about the status and trends associated with the bioeconomy-related assets. The most relevant items for comparative analysis of non-tangible and qualitative information from national report is outlined in Table 5 below.

*Table 5: Qualitative information from the national report on bioeconomy potentials used in the synthesis report*

| Bioeconomy-related asset | Topic |
|---|---|
| Industrial Initiatives | Consolidated firms in conventional bioeconomy sectors expanding their scope towards circular |
| | Industrial-scale biobased manufacturing |
| | Availability of private funding |
| | Role of bioeconomy in national Smart Specialisation Strategies |
| | Bioeconomy-hubs, networks, clusters |
| Research, Development and Innovation | RDI institutions actively engaging in applied bioeconomy research |
| | Cooperation of RDI institutions with industrial partners |
| Bioeconomy-related strategies and policies | Dedicated national BE strategy |
| | Dedicated policy instruments |
| | Level of inter-ministerial coordination on bioeconomy issues |

## 2.7. Sustainable business models and scenarios for closing material and energy loops of biomass

Bioeconomy is a relatively young concept in the economic literature and as such is still largely unexplored in the theory of business models. In connection with business models, the authors often start from the broader (and more researched) concept of sustainable business models. The same applies to the source that we summarize when describing the characteristics of business models in the bioeconomy in this chapter (Viira et al., 2021). It is based on the categorization of archetypes of sustainable business models (Bocken et al., 2014) and in some places adapts it to the specifics of relations between economic entities in the (circular) bioeconomy. The archetypes of business models in the bioeconomy and the description of their characteristics are summarized in Table 6 below.

*Table 6: Adapted archetypes of sustainable business models, applicable tot he context of (circular) bioeconomy business models (Viira et al., 2021)*

| Type of innovation | Archetype of business model | Value proposition | Value creation and delivery | Value capture |
|---|---|---|---|---|
| Technological | Maximization of material and energy efficiency | Products and services using fewer resources to reduce waste, emissions and pollution | More efficient production processes using less resources and reducing waste | Cost reduction from optimized use of resources, reduction of waste and environmental impact |
| | Creation of value from waste | Eliminating waste by turning waste into input for other production | Recycling of waste and closing of resource loops and making use of under-utilized capacities | Cost reduction from reuse of materials, reduction of waste and virgin material use |
| | Substitution with renewables and natural processes | Products based on Renewable resources and natural processes | Innovative production processes based on renewable resources, energy and natural systems | Revenues from new products, reduction of environmental impact of non-renewable resources use |
| Social | Delivery of functionality, rather than ownership | Shift from selling physical products to consumers to providing services for users | Redesign and delivery product/service offerings based on reuse, reparability and upgradability | Revenue for provision of services and increased access for consumers |
| | Adoption of stewardship role | Products and services for ensuring stakeholders long term well-being | Production and supply systems that deliver the environmental and social benefits | Revenues from the stewardship and benefits from the well-being of the stakeholders |
| | Encouragement of sufficiency | Product and services aiming to reduce consumption and production | Promotion of less consumption and less waste and more durable products | Revenues from durable products, environmental and social benefits from reuse and less consumption |
| Organizational | Re-purpose of the business for society and environment | Prioritization of social and environmental benefits over economic profit | Development of products and services with participation and integration with local communities and stakeholders | Environmental and social benefits from locally embedded enterprise |
| | Development of scale-up solutions | Large scale delivery of sustainable solutions | Development of channels and partnerships for scale-up solutions | Revenues for scaling up (e.g., franchising, licensing fees) and benefits from partnerships |

## 2.8. Scenarios for closing material and energy loops of biomass

Based on the archetypes of sustainable business models (Table 6) and on a detailed analysis of biomass side streams of agri-food, forest-wood and aquatic origin aquatic in national reports, the synthesis report suggests the most expedient scenarios of valorising biomass streams in accordance with the principles of circular economy (maximising economic, social and ecological benefits with the cascading use of resources. For the sake of robustness, the synthesis report distinguishes between three scenarios, which differ in terms of their (technology, organization, investment needs) complexity. They are briefly presented in Table 7 below.

*Table 7: Scenarios for closing material and energy loops of biomass*

| | Scenario 1: improved management - closing loops at the production site | Scenario 2: Industrial symbiosis - improved technologies and processes | Scenario 3: Extended value chains - improved technologies, processes and value chain management |
|---|---|---|---|
| **Characteristic feature** | Closing material flows at the plant, farm or company level | Vertical (intra- or inter-sectoral) cooperation, where waste becomes a secondary raw material for products of another firm or sector | Cooperation (vertical and horizontal; cross regional, also international) among economic entities along extended value chains; entails not only production, but also innovation management / tech transfer and marketing mix |
| **Economic impacts, environmental and social benefits** | Direct (cost reduction, additional revenues) and indirect (new markets, branding) economic benefits; reduction of environmental impacts, development of sustainable biobased products/services limited to the sole producer | Economic benefits mutually shared among participants; environmental effects extended along the value entire chain; emphasized social social effects (new jobs with the development of new services - logistics processes) | Induced (demand-pull) improvements along the extended value chain (operators in 'novel' bioeconomy sectors bring new demand, firms in 'conventional' bioeconomy sectors incentivised to adapt); largest aggregate impact |
| **Challenge** | Know-how, investment (firm-level) | Investment of all stakeholders in the improvement of technologies and processes (eg. Logistics, pre-treatment, optimization of procurement and processing technologies) | Distribution (territorial, sectoral) of impacts not necessarily balanced, depending on the relationships along the (extended) value chain |

## 2.9. Land use and land use intensity

The BIOECO-UP region covers 997.531 km$^2$ of land of which 878.484 km$^2$ (88%) is available for biomass supply (Table 8). Poland and Italy are by far the largest BIOECO-UP countries, and together they cover more than half (62%) of that area. As shown in Figure 3 woodland represents more than 44% of land cover in the BIOECO-UP region, followed by grassland (23%), cropland for cereal production (18%) and cropland for other crops (16%). In Slovenia (59%) woodland covers more than half of the land available for biomass production, followed by Austria and Slovakia (both 43%), Italy (37%), Czech Republic (36%), Croatia (30%), while Hungary has the lowest share of woodland (23%). Generally, cereals cover (15%) of total land available for biomass production in the BIOECO-UP countries. The lowest share is noted for Slovenia (7%), Austria and Croatia (both 9%) and the highest for Hungary (29%) and Poland (24%).

*Table 8: Total sum for key categories of land use in total land use available for biomass production in BIOECO-UP countries in 2018 (data source: EUROSTAT, 2023)*

| Land area ($km^2$) | Italy | Czech Republic | Austria | Croatia | Hungary | Poland | Slovenia | Slovakia |
|---|---|---|---|---|---|---|---|---|
| Total land cover | 302.073 | 78.874 | 83.878 | 56.539 | 93.013 | 313.931 | 20.277 | 49.026 |
| Cropland | 100.129 | 8.645 | 19.366 | 4.216 | 14.101 | 28.349 | 702 | 4.641 |
| Cereals | 29.783 | 16.619 | 7.474 | 5.205 | 26.522 | 75.212 | 1.232 | 8.399 |
| Grassland | 36.248 | 17.598 | 17.300 | 10.797 | 18.486 | 70.470 | 4.391 | 9.555 |
| Woodland | 97.569 | 28.520 | 36.362 | 18.097 | 21.431 | 107.486 | 12.125 | 21.454 |

When comparing cropland and grassland, the latter is especially significant in Slovenia, where grassland area is more than twice as large as the country's cropland area. Higher importance of grassland in the structure of land use can also be noted for Croatia, Poland and Czech Republic, where grassland represents 28%, 25% and 24% of total land available for biomass production.

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