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D3.1

Results from multi-dimensional competency and biomass mapping

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Abbreviations

AHP	Analytical Hierarchy Process
BII	Biodiversity Intactness Index
CBB	Circular Bio-based
CEE	Central Eastern European
Dmnl	Dimensionless
EU	European Union
Exp	Export(s)
GERD	Gross domestic expenditure on research and development
GDP	Gross Domestic Product
GHG	Green House Gas Emissions
GVA	Gross Value Added
Imp	Import(s)
JRC	Joint Research Centre (EU)
kg CO_2-eq	kilogram of CO_2 equivalents (equivalent to the effect of 1 kg of CO_2 emission)
KoM	Kick-off-Meeting
LULUCF	Land Use, Land-Use Change and Forestry
m^3/t	cubic metres of water use per tonnes of biomass produced
MS	Member State
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
T	Task
TRL	Technological Readiness Level
t C/ha/year	tonnes of carbon per hectare per year (rate of soil organic carbon change)
t/ha/year	tonnes per hectare per year
WP	Work Package
€/t/year	Euros per tonne per year
€/ha/year	Euros per hectare per year

Introduction to the project

BOOST4BIOEAST *is a Coordination and Support Action funded by the European Commission developed to support the BIOEAST Initiative with the aim of empowering national stakeholders in the Central Eastern European and Baltic countries for the development of national bioeconomy action plans and to build long-lasting structures and spaces of dialogue for national and macro-regional cooperation. The project will enrich knowledge on the bioeconomy and stimulate related research and innovation across the macro-region.*

Executive Summary

This deliverable outlines the development of a multi-dimensional indicator framework designed to assess national readiness for the bioeconomy. The approach focuses on four critical categories: workforce skills (social competencies), technological readiness (technological competencies), business and innovation environments (economic competencies), and national biomass potential. By leveraging a robust indicator framework, the methodology bridges the gap between available data and actionable insights, enabling BOOST4BIOEAST HUBs to support informed decision-making at the national level.

During the first year of the BOOST4BIOEAST project, monitoring needs in each of the four categories were identified and validated with project partners. These monitoring needs served as a baseline for the extensive literature review of academic articles, EU project reports, and established indicators. This process informed the development of an initial indicator catalogue, which was subsequently prioritised per category by national HUBs to define core indicators.

Indicators were characterised with a description of their purpose, definition and assessment method by DBFZ (competency indicators) and BME/TKK (biomass potential indicators). Utilising a *Guideline for Indicator Assessment* (García Laverde, *et al*., 2024) (hereafter the Guideline) as tool to document the indicator framework and its methodology, the framework was first shared with four voluntary HUBs for testing, namely Slovakia, Romania, Hungary, and Latvia. Feedback from the testing phase coupled with valuable revisions from the testing countries, allowed for the refinement of the methodology, and ensured its adaptability to national contexts. Finally, the revised Guideline was shared with all other HUBs to commence the indicator assessment phase across all countries.

The finalised indicator framework and its core indicators are presented in this report, encompassing 29 competencies indicators and 35 biomass potential indicators. Additionally, an overview of the planned steps for the indicator assessment within Work Package (WP) 3 is presented at the end of the report and their relevance for other work in BOOST4BIOEAST. In particular, the results of indicators will be essential for:

- Establishing national bioeconomy actions plans in WP7.
- Conducting a gap analysis in Task (T) 3.3 by identifying desired levels per indicator, per country.
- Deriving insights for policymakers in T3.4.

Through the application of the indicator framework, key areas for development will be identified, supporting BOOST4BIOEAST countries in advancing their national bioeconomies. The structured methodology offers a practical and maintainable approach to address the complexities of national bioeconomy readiness.

1 Introduction

Empowering stakeholders in the BIOEAST macro-region and supporting their collaborative efforts is essential to accelerating the transition toward a sustainable bioeconomy. The BOOST4BIOEAST project as part of supporting Central Eastern European (CEE) and Baltic countries to develop national bioeconomy action plans, also strengthens its national stakeholders by enriching knowledge in bioeconomy-related competencies and biomass. Opportunities remain in the region to leverage the abundant agriculture and forestry biomass resources, alongside other critical supportive structures such as workforce skills and knowledge, technological readiness and infrastructure, and innovative ecosystems for bio-based businesses.

In guiding the development of the bioeconomy in the macro-region, it is of utmost importance to have decision-making tools to identify strategic priorities. A necessary step is to assess the sustainable production potential of the primary sector in each BIOEAST country. While some information regarding biomass availability and utilisation is already available in databases (e.g. Eurostat), a deeper understanding of the sustainability of biomass provision, the added value of biomass integration in bioenergy and biomaterial production system, and finally the quality of existing biomass-related data can yield additional information to decision-makers.

On the other hand, it is also key to assess a country's systemic capabilities to efficiently use these resources in a sustainable manner (i.e., bioenergy and biomaterials). Among the systemic competencies of the countries, three main categories have been selected in BOOST4BIOEAST, namely available workforce skills (social competencies), technological readiness (technological competencies), and business and innovation environments (economic competencies).

By developing a robust indicator framework - encompassing both structure and measurement - for a comprehensive multi-dimensional biomass and competency mapping and providing it to BOOST4BIOEAST HUBs for their assessment at national level, this work aims to bridge the gap between available data and actionable insights. **This deliverable aims to present the used methodology and results for a multi-dimensional mapping of bioeconomy-related competencies, as well as biomass availability and use, developed during the first year of the BOOST4BIOEAST project.** The process involved assessing monitoring requirements and priority areas by the HUBs and revising past and ongoing initiatives to identify existing indicators, resulting in the creation of a catalogue of indicators. The overarching goal of the developed indicator framework and its assessment methodology is to support the assessment of a national readiness level for the bioeconomy. This goal is intended to be reached through the application of the indicator framework, supported by a goal-setting system utilising an Analytical Hierarchy Process (AHP) method in T3.3. Results of the indicators will provide a measure to track progress towards established goals.

This deliverable presents the methodology followed for selecting, prioritising and testing the main indicators for the multi-dimensional biomass and competences mapping in Chapter 2. Main considerations and steps taken to validate the final core indicators are explained in Chapter 3. Also, details regarding assessment methods and following steps for their assessment by the HUBs are outlined in this chapter along with additional recommendations provided to BOOST4BIOEAST HUBs for the application of the indicators.

The results of the indicator framework can significantly enhance decision-making processes. It can also enable the prioritisation of interventions in the macro-region tailored to each country's unique context, fostering regional collaboration and sustainable growth in the bioeconomy. This approach aims to empower policymakers, industry stakeholders, and researchers to make informed decisions, allocate resources effectively, and pursue strategic actions that align with both national and macro-regional bioeconomy objectives.

2 Methodology

2.1 Identifying main needs for the indicator framework

To identify pressing needs for the biomass and competences monitoring, two main sources were utilised. The first was a literature review conducted to gain insights into existing assessment methods for the monitoring categories, (e.g. circularity indicators, bioeconomy monitoring indicators, biomass mapping), which were further explored while defining the indicators (See section 2.2). These categories have been chosen in WP3 to reflect the critical areas influencing the bioeconomy - workforce skills to support bioeconomy development, technological capabilities for innovation, economic environments for fostering growth, and biomass availability as the foundation for sustainable resource utilisation.

The second source was consultation with BOOST4BIOEAST partners, in particular country representatives and to identify monitoring needs in each of the categories. These have been partly collected during the project proposal preparation with questionnaires on user requirements for the competency and biomass mapping. Partners representing the intended HUBs indicated key needs and how would they use the potential results of the monitoring, including specific use cases. The BOOST4BIOEAST project Kick-off Meeting (KoM) held on 5th March 2024 served to complement this information. During this event, project partners participated in a workshop, designed to identify needs and set the framework for the multi-dimensional mapping in WP3. Four tables were organised, focusing on the social, technological, and economic competences, and on biomass mapping. In each table, needs regarding the mapping of each dimension were asked to participants and their suggestions about mapping methods. As a final question, participants could also propose exemplary initiatives (e.g. EU/national projects) and exemplary indicators that could be utilised to inform specific needs.

Main needs uncovered for the indicator framework are summarised hereafter:

- **Biomass potential**
  Key needs for the mapping of biomass availability underlined a comprehensive assessment of biomass origins, including terrestrial crop production, grazed biomass, wood, aquatic biomass, and various residues and side-streams (e.g., harvested residues, food industry by-products, biorefinery residues) as well as biomass imports. It included suggestions for detailed overview of biomass feedstock forms—solid (plant material, wood, forest residues, food waste), liquid (sewage, industrial by-products), and gaseous (methane from livestock)—with a particular focus on energy-dedicated sources such as agricultural residues, forestry by-products, algae, and municipal waste. Categories such as biomass use across sectors were also proposed: food and animal feed, biomaterials (e.g., agrochemicals, pharmaceuticals, fibres, polymers), energy production, and exports.
  Infrastructure aspects, including collection points, conversion sites, and integration into local and regional value chains, were mentioned. Also, forward-looking analyses of biomass flows, including future supply projections, seasonal availability, and potential risks to supply chains were suggested. Furthermore, key metrics like nutrition values, wet and dry weight, carbon content, greenhouse gas (GHG) emissions, and associated monetary flows to capture the sustainability and economic value of biomass resources were taken into consideration. Finally, other aspects were mentioned such as understanding biomass collection models and supply chain risks to support more resilient and efficient biomass utilisation.

- **Social competences**
  Key needs for the mapping of social competences highlighted the availability of transversal skills such as systemic thinking, transdisciplinarity, and green skills, alongside project management and facilitation abilities among bioeconomy stakeholders. Vocational training opportunities, entrepreneurship education, and project/venture finance skills were also mentioned. Other mentioned aspects included attention to skills in rural areas where bioeconomy knowledge gaps still exist. Additionally, exploration of advisory services, social acceptance, knowledge-sharing networks, and the adaptability of educational content were also mentioned. Including also the demand for industrial and digital skills, technology transfer mechanisms as essential to address current and future workforce needs in the bioeconomy sector.

- **Technological competences**
  Key needs for the mapping of technological competences underlined a focus on assessing the capacity for process innovation in bioeconomy sectors, particularly in developing added-value product processes. This included the integration of efficiency

and circularity principles in bioenergy and biomaterials production. The state of technical infrastructure—such as conversion technologies, outdated systems requiring upgrades, pilot plant facilities, lighthouse projects, and high-tech installations—was also included. Additionally, it was suggested for the mapping to capture the availability and adoption of emerging and circular bio-based technologies, biowaste recycling systems, and agrowaste reuse technologies. Understanding the alignment between available biomass resources and applicable technologies, the accessibility of national funding for technology innovation, and the role of research infrastructure and digital tools in supporting technological advancement to foster bioeconomy development were also mentioned.

- **Economic and structural competences**
  Key needs for the mapping of economic and structural competences focalised on the availability and effectiveness of financial instruments, such as risk-sharing mechanisms and targeted financial products that support bioeconomy projects, particularly during critical scaling-up phases from pilot to industrial scales. This includes evaluating government-funded ventures, fiscal and policy incentives, and accessible financing opportunities. The mapping could also cover sustainable and innovative business models, new value chains, stakeholder networks, project partnerships, support systems to bio-based businesses such as the presence of support institutions and their activities (e.g. availability of advisory and mentoring services).

It is important to clarify that, although these key needs are highlighted due to their significance, not all could be translated into indicators. The process of transforming these needs into potential indicators within our methodology involved assessing their feasibility, primarily influenced by data availability. In the following section the process to translate these needs into measurable indicators is detailed.

2.2 Process to reach the final core indicators

2.2.1 Defining an initial indicator´s catalogue

To address the identified needs and their translation into measurable indicators, a further comprehensive literature review was conducted for each of the identified dimensions and exemplary initiatives or examples provided by project partners. This review included academic articles, EU project reports (Viaggi & Chatzinikolaou, 2022), preliminary initiatives in the BIOEAST macro-region, as well as in other EU countries (Siedschlag, Yan, & Meneto, 2022) (Wydra, Reyhani, Hüsing, & Schwarz, 2023), EU indicator frameworks (Replace, 2024) (Becqué, *et al*., 2021) (Commission, 2024) (Commission, 2023) (Eurostat, 2024) (Parisi, Baldoni, & M'barek, 2022) and documentation from other trustworthy institutions (e.g., the Organisation for Economic Co-operation and Development - OECD) (OECD, 2017) (OECD, 2023). Among many other sources, which can be consulted in the final Guideline presenting and explaining the final

indicator framework. These sources helped to identify initial indicators, validate assessment needs, and provide background information to support the development of the indicator framework.

The results from the literature review and insights from the workshop were combined to develop an initial catalogue of indicators. To ensure no critical elements were overlooked project partners were encouraged to identify national initiatives relevant to the proposed indicators. Their feedback and suggestions for improvement were integrated into refining the methodology and the definition of a first list of indicators. As a result of these steps, an initial indicator catalogue with 62 indicators was developed, covering social, technological and economic competencies, as well as 23 biomass-related metrics across 37 biomass types. Each indicator was accompanied by a description and references.

2.2.2 Prioritisation of indicators

The next step focused on identifying the most relevant indicators in each category to effectively monitor national bioeconomy readiness. To achieve this, HUB Coordinators were asked to prioritise all the indicators in the initial catalogue within each category. This process was facilitated through LimeSurvey, an online survey tool, where each country ranked the indicators by their perceived importance.

The collected priority rankings from all HUBs were systematically analysed to establish a unified ranking order. This order was determined by calculating the average rank of each indicator across all participating HUBs, which provided a clear picture of the key indicators of interest for each country. Based on this analysis, the Top 10 indicators in the subcategories of social, technological, economic, and structural competencies were selected. For biomass-related indicators, 15 metrics covering production, economics, usage, and environmental costs were selected across 20 high-priority biomass types. Additionally, indicators that were highly rated but not selected solely based on ranking were reconsidered. These were either integrated with similar indicators or maintained as standalone indicators due to their strategic relevance.

With the final list of indicators, began a transversal process with T3.3 to define and structure them based on a goal system. This is done based on the AHP methodology (Saaty, 1980), applied for complex decision processes. It involves defining a hierarchy where the indicators are organized and categorized based on contributions to sub-ordinated goals, which add to an overarching goal for a systemic analysis. The overarching goal was defined as high national readiness level for the bioeconomy. Further development of the goal-system will continue in the framework of T3.3. Current drafts of the AHP structure both for the competency and biomass potential indicators are depicted in Figure 1 and Figure 2, respectively.

2.2.3 Creation of a Guideline to support the assessment of indicators

Following the prioritisation of indicators, it was essential to establish a practical framework to guide HUB Coordinators in evaluating these indicators effectively and to facilitate country´s comparability. This led to the development of the **Guideline** designed to provide a consistent framework for assessing a country's readiness for the bioeconomy, based on the four selected monitoring categories.

The Guideline offers comprehensive information on the indicator methodology, detailed assessment methods, and the necessary resources to enable HUBs to independently conduct thorough evaluations. It includes explanations for each category and sub-category, instructions for engaging relevant stakeholders in data collection, and in-depth descriptions of each indicator.

To ensure clarity and consistency, a factsheet was developed for each indicator, structured to include the following components:

- **Purpose**: A brief explanation of the intended outcome and relevance of each indicator.
- **Operational definition:** A clear, research-backed definition derived from literature reviews and the initial indicator catalogue, supplemented with information for a clear understanding of what the indicator measures. Limitations are also provided for clarity.
- **Assessment method:** The methodology for evaluating the indicator, determined after classifying it as either quantitative or qualitative.
- **Type:** Classification as quantitative (using existing measurement methods and data sources like Eurostat) or qualitative (assessed using a three-level or five-level scale).
- **Data sources/Examples:** Relevant data sources and examples of related initiatives to support comprehensive assessments.
- **References:** Supporting documentation and literature for validation.

Quantitative indicators rely on established data sources, while **qualitative indicators** are evaluated using a scaled scoring system to assess qualitative performance. Depending on the indicator category, this scoring has been defined as a three-level (1 = lowest value, 3 = highest value) or a five-level scale (1 = lowest value, 5 = highest value). For social, technological, economic, and structural competencies, survey protocols are applied to determine country-specific scores.

To facilitate consistent reporting, an Excel template titled **Template for reporting indicators** was developed (7 Appendices

Appendix 1 – Template for reporting indicators). This tool aids countries in documenting their indicator results and referencing relevant data sources effectively.

This structured approach ensures that HUB Coordinators are equipped with the necessary tools and guidance to perform consistent and meaningful assessments across all participating countries.

2.3 Testing the methodology for indicator assessment

A testing phase was deemed essential to identify potential data gaps, issues with measurement methods and address any methodological ambiguities. It also allowed for the consideration of country-specific contexts, increasing the framework's adaptability and acceptance. Two countries were pre-selected during the proposal phase (Slovakia and Romania), and two more volunteered to participate in the testing phase (Hungary and Latvia).

The Guideline was shared with the selected testing countries on 8 August 2024. The testing phase was officially launched with an online Kick-off Meeting on 18 August 2024. During this meeting, the purpose of the indicator framework was explained, first impressions of the Guideline were discussed, and a detailed work plan for the testing phase was agreed upon. Indicators related to social competencies and biomass potential were distributed among the four countries, ensuring each indicator was tested by at least two countries for comparison.

A timeline was set for testing the indicators throughout August and September, with two follow-up meetings scheduled for clarifications and feedback. The testing period was later extended until November 2024 to accommodate for received feedback and integrate necessary adjustments to the core indicators and their assessment method. Two follow-up group meetings were held on 1 and 25 October 2024. Additionally, bilateral meetings with each country took place between 13 and 20 November 2024, to review and refine assigned indicators.

Feedback based revisions of core indicators

Feedback from the testing countries was collected either during the follow-up or bilateral meetings, as well as through email during the testing phase (August to November). The key insights that have been incorporated into the revised Guideline include:

- **Biomass potential**: Feedback received made clear that the final list of indicators can be reduced from the initially proposed matrix of 15 metrics across 20 biomass types. The comments also highlighted that most indicators can be directly extracted from various databases, are already being monitored by other initiatives, and it is unclear whether they sufficiently describe a country's biomass potential. Therefore, in the revised Guideline, the indicators in this subcategory were reworked into a set of 35 more complex core indicators common to all countries, to explore biomass production and valorisation at the national level. Information on the environmental impact of biomass production, as well as the accessibility and currentness of relevant biomass-related data will also be gathered.

- **Proposal to conduct surveys in exchange to expert interviews for qualitative questions**: Instead of relying on expert interviews and desk research, testing countries proposed using surveys targeted at public administrations and the bioeconomy sector. In the revised Guideline, survey protocols are provided, to be translated in national languages by HUB Coordinators. Likewise, indications about preparation, conduction and analysis of surveys have been included in the Guideline.
- **Definition of criteria to specify level of expertise:** Some indicators require expert responses, either for the surveys or interviews. A set of criteria has been established to guide the identification of experts in each country, ensuring consistency and homogeneity in the assessment process.

3 Results

This section presents the final core indicators selected for the indicator framework. Based on the four selected categories of the framework and sub-categories identified during its development, the assessment of a national readiness level for the bioeconomy is aimed. The indicator framework is the backbone of a goal-based assessment that will be continued in T3.3. Results of the indicators will provide a measure to track progress towards established goals.

3.1 Final core indicators

The revised and final core indicators in the four selected categories, namely for the social, technological and economic competences as well as for the biomass potentials are here below presented.

3.1.1 Social competencies

Social competencies represent skills and knowledge (human capabilities). In BOOST4BIOEAST, those required by public administrative bodies and bioeconomy sectors of relevance to the Member State (MS) are considered. The main objective of the social competencies indicators is to express the readiness of key skills and knowledge that are important to support the development of the bioeconomy in the country.

The indicators expressing social competencies are subdivided into *Public administration* and *Bioeconomy sector*. Details regarding the understanding of each sub-categories, are included in the Guideline.

Table 1. Final list of social competencies indicators (Qualitative indicators, scored through a scale of 1 to 5 are marked as dimensionless – Dmnl)

Sub-category	Indicator	Description
	S.1. Circular economy skills (Dmnl)	Knowledge about and ability to apply circular economy principles.

Public administration	S.2. Systemic thinking skills (Dmnl)	Knowledge about and ability to apply systemic thinking.
	S.3. Sustainability and environmental protection skills (Dmnl)	Knowledge about and ability to apply sustainability and environmental protection skills.
	S.4. Communication skills (Dmnl)	Knowledge about and ability to apply communication skills.
	S.5. Project management skills (Dmnl)	Knowledge about and ability to apply project management skills.
Bioeconomy sectors	S.6. Skills demanded by the bioeconomy sector (Dmnl)	Availability of skilled labour that match the skills required by the bioeconomy sector.
	S.7. Innovation skills (Dmnl)	Knowledge about and ability to apply innovation skills.
	S.8. Entrepreneurships skills (Dmnl)	Knowledge about and ability to apply entrepreneurship skills.
	S.9. Digital skills in bioeconomy sectors (Dmnl)	Knowledge about and ability to apply digital skills.

3.1.2 Technological competencies

Technological competencies represent the innovation and technical capabilities of the country to utilise biomass resources into higher added-value intermediate and final products. The indicators in this category, examine existing infrastructure and technological capabilities with consideration of circularity practices, such as utilisation of residual biomass or cascades use, for bioenergies as well as for biomaterials production. For the latter, there is a particular focus on chemical biorefineries due to their importance as building blocks for other bio-based materials, such as biopolymers, and as intermediates for a variety of end-use sectors. The research, development and innovation capabilities are also examined by a section of technological indicators. Research and development (R&D) advances in biomethane, advance liquid biofuels, as well as biochemicals, both at early stages (Technology Readiness Level - TRL 3-5) and at pilot plant or demonstration facilities (TRL 6-8). For the analysis of biorefineries, related to the monitoring of biochemicals production, the adopted definition given by the Joint Research Centre (JRC) (Parisi, 2018) is used.

Table 2. Final list of technological competencies indicators (Qualitative indicators, scored through a scale of 1 to 5 are marked as dimensionless – Dmnl)

Sub-category	Indicator	Description
Mature Circular Bio-based (CBB) industry	T.1. Biomaterial replacing non-renewable resources (substitutes) (%)	Share of bio-based products in total consumption.
	T.2. Circular material use rate (%)	Share of material recycled and fed back into the economy.
	T.3. Number of bioenergy and biorefinery plants at national level (TRL 6 or higher) (Dmnl)	Number of bioenergy and biorefinery plants with TRL 6 or higher.
	T.4. Bioenergy plants and biorefineries using residual biomass or by-products in their processes (Dmnl)	Number of bioenergy and biorefinery plants that use residual biomass/by-products.
R&D	T.5. Number of research projects and process development (TRL 3-5) for bioenergy and biorefineries in the country (Dmnl)	Number of research projects and development processes for bioenergy and biorefineries.
	T.6. Gross domestic expenditure on R&D (GERD) at national level (%)	GERD as a percentage of the gross domestic product (GDP) to measure commitment to technological development and innovation.
	T.7. Number of bioeconomy patents submitted (at national level) (Dmnl)	Number of patents applied to national and EU registries as indicator for technological advances and innovation progress.
	T.8. Technology transfer (Dmnl)	Existence and quality of transfer of technology from research centres to end-users.
Infrastructure for residues management	T.9. Infrastructure for collection and management of forestry residues (Dmnl)	Quality and readiness of infrastructure for collection, management and utilisation of forestry residues.
	T.10. Infrastructure for collection and management of agricultural residues and food industry sector residues/by-products (Dmnl)	Quality and readiness of infrastructure for collection, management and utilisation of agricultural and food industry residues/by-products.

	T.11. Infrastructure for collection and management of other biomass residues (e.g. urban and municipal biological waste) (Dmnl)	Quality and readiness of infrastructure for collection, management and utilisation of other biomass residues (e.g. urban/municipal biological waste).

3.1.3 Economic and structural competencies

Economic and structural competencies relate to bioeconomy business models and the systemic framework that support them. This includes systemic structures to nurture entrepreneurship and to support new business models, such as services of business development organisations, accelerators, incubators or aspects related to business-science collaboration.

Table 3. Final list of economic and structural competencies indicators (Qualitative indicators, scored through a scale of 1 to 5 are marked as dimensionless – Dmnl)

Sub-category	Indicator	Description
Market environment	E.1. Value added of the bioeconomy sectors (€)	Economic contribution of the bioeconomy.
	E.2. Turnover in the bioeconomy sectors at national level (€)	Turnover from bioeconomy sector as a measure of revenue streams.
	E.3. Stakeholder networks that facilitate collaboration among bioeconomy actors (Dmnl)	Existence and quality of a network that aim to inform about and connect bioeconomy actors (e.g. clusters, hubs).
	E.4. Advisory services focalised on rural bioeconomy businesses (Dmnl)	Existence and quality of advisory services available to rural bioeconomy businesses.
	E.5. Supportive policy mechanisms for market uptake of bio-based products (Dmnl)	Existence and quality of policy mechanisms aimed at creating favourable conditions for the uptake of bio-based products.
	E.6. Existence of national bioeconomy investment and investor platform (for investors and entrepreneurs) (Dmnl)	Existence and quality of platform that connects investors with bioeconomy projects and vice versa.
Market push/innovation environment	E.7. New value chains for bio-based products (Dmnl)	Number of newly developed bio-based products that were brought to the market in the last 5 years.
	E.8. Supportive structures to novel business models in the (circular) bioeconomy (Dmnl)	Availability of supportive structures that promote bioeconomy related start-ups.

	E.9. Number of projects scaling up from pilot to demonstration projects as a result of being funded by private/venture funds (Dmnl)	Number of pilot projects (TRL 3-5) that scaled up to a demonstrations plant (TRL 6-8) due to public/private financial support.

3.1.4 Biomass potential

The proposed set of indicators is designed to comprehensively assess a country's sustainable biomass production and valorisation potential. These 35 indicators encompass three main dimensions: *biomass production* (B1.1-16), *biomass valorisation & economic potential* (B2.1-11), and *data quality & accessibility* (B3.1-8). Together, they provide a robust framework for evaluating the capacity, readiness, and sustainability of national biomass resources to contribute to a thriving bioeconomy.

Sustainable biomass production is a cornerstone of the bioeconomy, enabling the transition to renewable energy, bio-based products, and sustainable agricultural practices. To support this transition, it is essential to evaluate the availability, efficiency, and sustainability of biomass resources. The indicators help measure critical aspects such as biomass yields, as well as land and water use efficiency, carbon footprints, and biodiversity impacts, ensuring the alignment of production practices with sustainability goals.

Equally important is the understanding of the economic potential of biomass, from its contribution to national GDP to its valorisation into high-value products such as chemicals and materials. These economic indicators provide insights into the added value generated by biomass producers and the bio-based industries. Finally, the indicators on data availability and quality ensure the foundation for reliable and evidence-based decision-making, highlighting areas where data gaps or outdated information could hinder strategic planning.

Table 4. Final list of sustainable biomass potential indicators

Category	Indicator	Description
Sustainable provision of biomass resources	B1.1 Annual agricultural biomass production per total land area (t/ha/year)	Total quantity of agricultural biomass produced annually divided by the total land area of the country. It includes all biomass derived from agricultural activities.
	B1.2 Annual woody biomass production per total land area (t/ha/year)	Total quantity of woody biomass produced annually divided by the total land area of the country. It includes all biomass derived from forestry activities.

	B1.3 Annual aquatic biomass production per total water surface area (t/ha/year)	Total amount of aquatic biomass produced annually per unit of water surface area, including rivers, lakes, and marine territorial waters. It includes all biomass derived from fisheries and aquaculture activities.
	B1.4 Agricultural biomass production yields (t/ha/year)	Total agricultural biomass production divided by the total utilized agricultural area over a year. Utilized agricultural area is defined as the land area that is either arable, under permanent crops, or under permanent pastures.
	B1.5 Woody biomass production yields (t/ha/year)	It measures the total dry weight of woody biomass produced per hectare of wooded land during a calendar year in a country.
	B1.6 Aquatic biomass production yields (t/ha/year)	The total aquatic biomass (e.g., fish, algae) produced annually in aquaculture divided by the total area of cultivated water surfaces within the country.
	B1.7 Net exported agricultural biomass [= Exp - Imp] per total land area (t/ha/year)	It measures the net export of agricultural biomass, calculated as the difference between the total amount of agricultural biomass exported and imported on a per-hectare land area basis.
	B1.8 Net exported woody biomass [= Exp - Imp] per total land area (t/ha/year)	It measures the net export of woody biomass, calculated as the difference between the total amount of woody biomass exported and imported on a per-hectare land area basis
	B1.9 Net exported aquatic biomass [= Exp - Imp] per total water surface area (t/ha/year)	It measures the net export of aquatic biomass, calculated as the difference between the total amount of aquatic biomass exported and imported on a per-hectare water surface area basis.
	B1.10 Share of agricultural biomass of total biomass production (%)	It measures the proportion of agricultural biomass produced relative to the total biomass production in a given country.

	B1.11 Share of woody biomass of total biomass production (%)	It measures the proportion of woody biomass (e.g., timber, forestry residues, and other wood-based materials) relative to the total biomass produced in a country.
	B1.12 Share of aquatic biomass of total biomass production (%)	It represents the proportion of aquatic biomass (both marine and freshwater sources) relative to the total biomass production in a country.
	B1.13 Rate of soil organic carbon change (t C/ha/year)	It measures the rate of change in the mass of organic carbon stored in soil per hectare per 5 years.
	B1.14 Water use efficiency (m^3/t of biomass produced)	The amount of agricultural biomass produced per unit of water consumed in an agricultural system.
	B1.15 Carbon footprint (kg CO_2-eq/t of biomass produced)	The total greenhouse gas (GHG) emissions generated during the lifecycle of biomass in agriculture, fisheries, aquaculture, and forestry, including emissions from land use and land-use change (LULUCF).
	B1.16 Annual change in Biodiversity Intactness Index (BII) (%/year)	BII summarises the change in ecological communities in response to human pressures. It is an estimated percentage of the original number of species that remain and their abundance in any given area, despite human impacts.
Adding value to biomass	B2.1 Value of annual agricultural biomass production per utilized agricultural area (€/ha/year)	Enables the assessment of the economic efficiency of a (spatial) production unit and facilitates comparisons of value-creation capacity across different regions.
	B2.2 Gross Value Added (GVA) in agricultural biomass production per utilized agricultural area (€/ha/year)	Reflects the difference between the output value (e.g., crops, livestock) and the cost of inputs used to produce it (e.g., seeds, fertilizers, forage and energy).
	B2.3 Value of annual forestry biomass production per utilized forestry area (€/ha/year)	Enables the assessment of the economic efficiency of a (spatial) production unit and facilitates comparisons of value-creation capacity across different regions.

	B2.4 GVA in woody biomass production per utilized forestry area (€/ha/year)	Reflects the difference between the output value and the cost of inputs used to produce it.
	B2.5 Value of annual aquatic biomass production per total water surface area (€/ha/year)	Enables the assessment of the economic efficiency of a (spatial) production unit and facilitates comparisons of value-creation capacity across different regions.
	B2.6 GVA in aquatic biomass production per total water surface area (€/ha/year)	Reflects the difference between the output value and the cost of inputs used to produce it.
	B2.7 Value of bio-based products in proportion to national GDP (%)	Provides insight into how significant the bio-based economy is within a country's overall economic structure.
	B2.8 GVA in bio-based industries per tons of biomass converted (€/t/year)	Assesses the economic productivity of bio-based industries in utilizing biomass.
	B2.9 Share of conversion into energy in domestic biomass valorisation (%)	This metric is important for assessing the importance of the energetic use of biomass, particularly in the context of renewable energy adoption and sustainability.
	B2.10 Share of conversion into food and feed in domestic biomass valorisation (%)	Important for assessing the importance of the food and feed use of biomass, particularly in the context of food and feed supply security.
	B2.11 Share of conversion into chemicals and materials in domestic biomass valorisation (%)	Important for assessing the importance of the chemicals and materials use of biomass at a country level.
Detailed knowledge of biomass production and valorisation	B3.1 Availability of detailed data on biomass production (Dmnl)	Reflects the availability, granularity, and accessibility of data on national biomass production across key sectors, crops and species, as well as biomass types.
	B3.2 Availability of detailed data on biomass conversion (Dmnl)	Reflects the availability, granularity, and accessibility of data on converting biomass into valuable products across key bio-based industry sectors.
	B3.3 Availability of detailed biomass-related economic data (Dmnl)	Reflects the availability, granularity, and accessibility of economic data related to

		national biomass production and valorisation across key sectors.
	B3.4 Availability of detailed data on the environmental impact of biomass production (Dmnl)	Reflects the availability, granularity, and accessibility of data on the environmental impact of biomass production across key sectors and impact categories (e.g., soil erosion, water use, carbon footprint).
	B3.5 Currentness of data on biomass production (Dmnl)	Reflects the currentness of data on national biomass production across key sectors, crops and species, as well as biomass types.
	B3.6 Currentness of data on biomass conversion (Dmnl)	Reflects the currentness of data on converting biomass into valuable products across key bio-based industry sectors.
	B3.7 Currentness of biomass-related economic data (Dmnl)	Reflects the currentness of data on economic data related to national biomass production and valorisation across key sectors.
	B3.8 Currentness of data on the environmental impact of biomass production (Dmnl)	reflects the currentness of data on the environmental impact of biomass production across key sectors and impact categories.

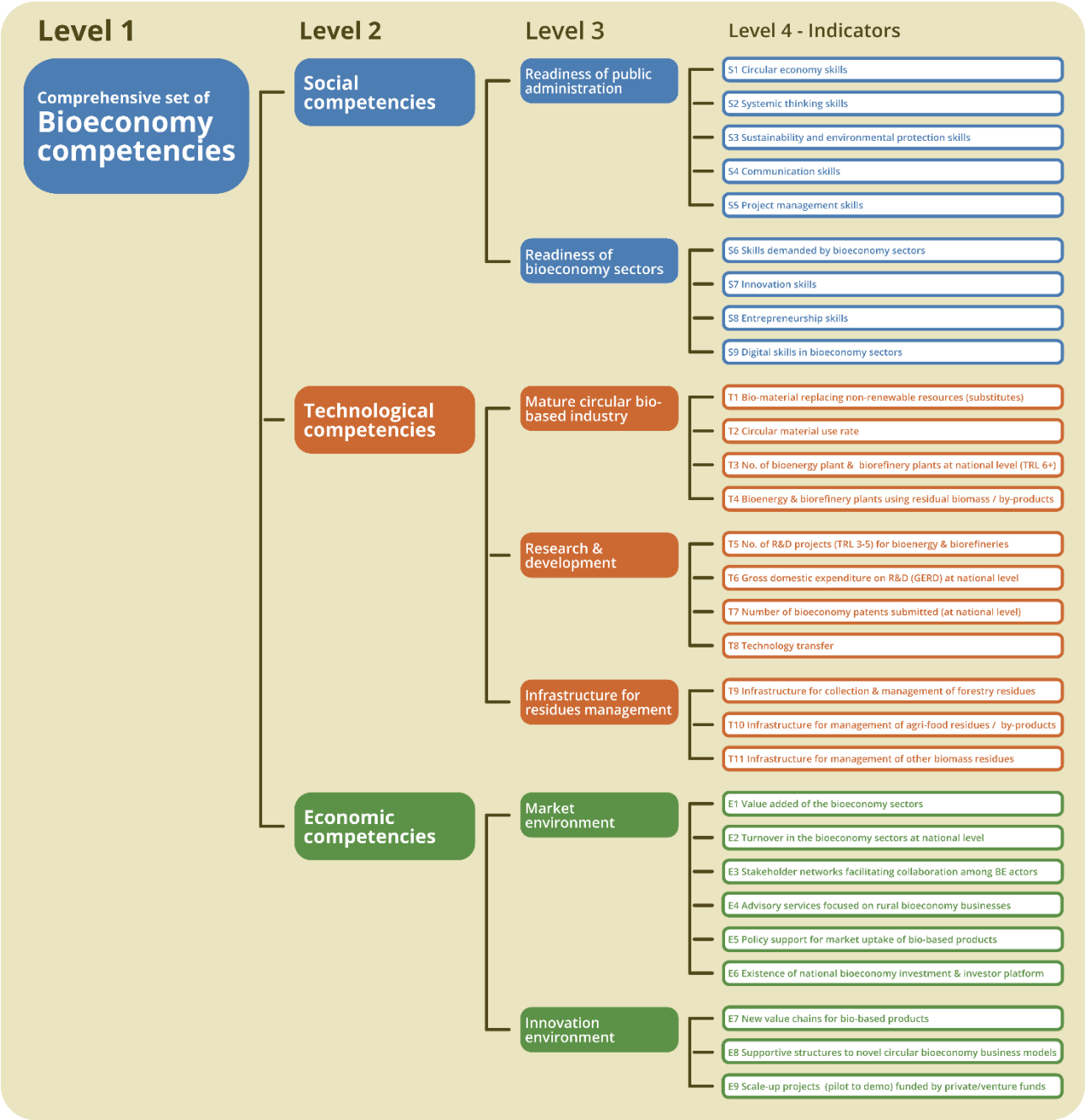

Figure 1. Drafted AHP goal system for the social, technological and economic bioeconomy-related competencies indicators

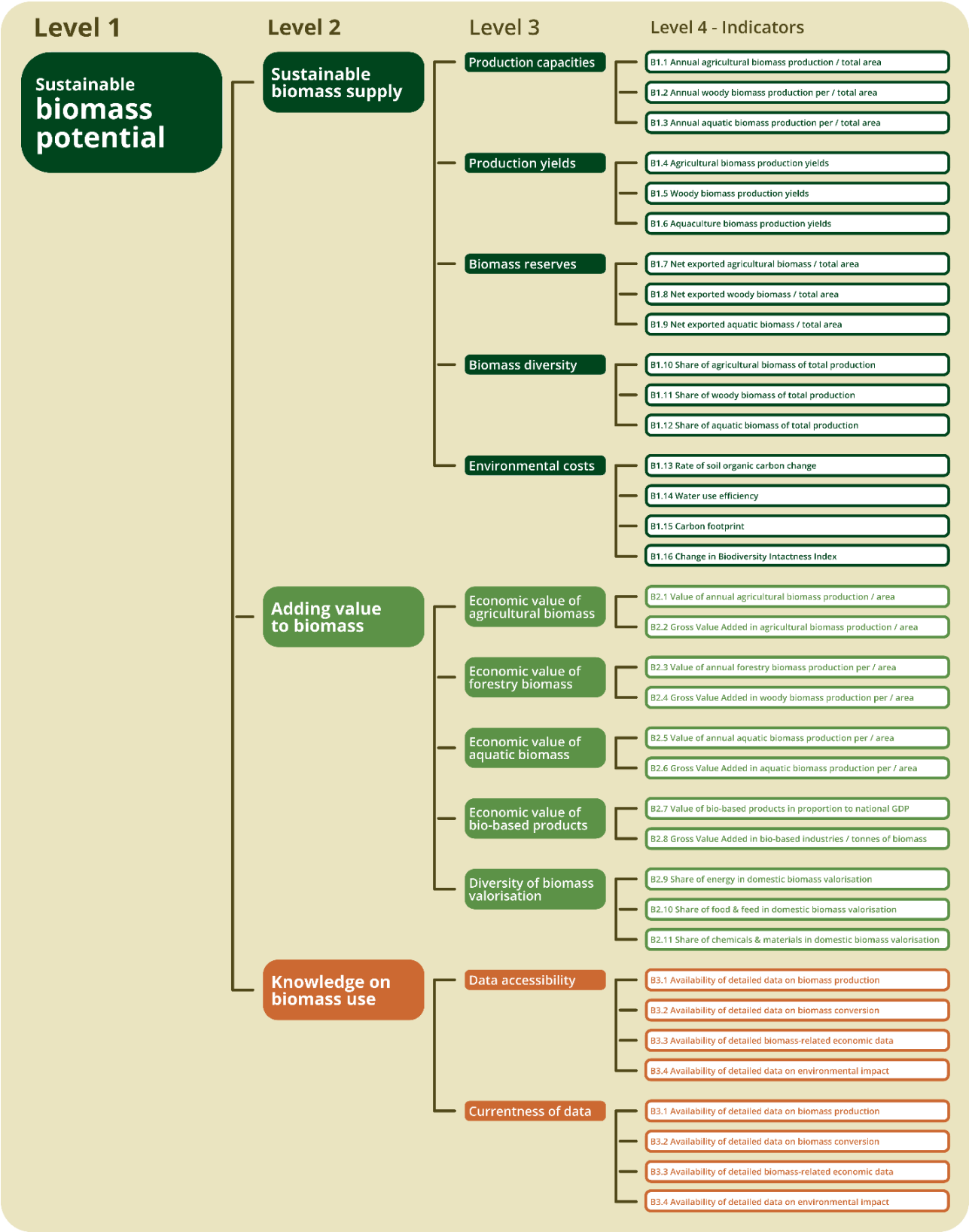

Figure 2. Drafted AHP goal system for the biomass potential indicators

3.2 Assessment methods considered in the indicator framework

Social Competencies

For the assessment of social competencies indicators, a survey has been developed to allow a self-assessment of skills and knowledge from target individuals. Details of the target respondents for each sub-category, namely public administration and bioeconomy sectors, are explained in the Guideline.

Results of the individual's self-assessment will be collected in a *five-point* scale, ranging from 1=Non-confident to 5=Very confident. To score the social competencies indicators based on the survey responses, a Likert-scale (Robinson, 2014) median scoring will be carried out.

Once the survey has been carried out and the score has been calculated for each indicator, the results are recorded in a ready-made template.

Technological competencies

Data collection from national and European statistics and other national resources (e.g. databases, ministerial reports) is the main source of information for the assessment of technological competencies indicators. These data collections will be researched and consolidated by the HUBs.

A survey has been developed to back the collection of information and assessment of qualitative characteristics of some of the indicators. However, it is to be understood as a supplementary source of information that collected through desk-research methods. The HUBs will be responsible to join the results of the survey with their desk-research data and define the final scoring of each one of these indicators. The survey protocol for selected technological competencies indicators is available in the Annexes of the Guideline.

Once the indicator value or score has been determined, it should be reported in the *Template for reporting indicators* (7 Appendices

Appendix 1 – Template for reporting indicators) created for the HUBs to fill in. In addition to the information on the results, the data sources that were used to reach the final indicator score or to assess it should also be indicated.

Economic competencies

For the assessment of economic competencies indicators, data collection from national and European statistics, as well as other national resources (e.g. databases, ministerial reports) are the principal source of information. These data collection is to be researched and consolidated by HUBs. A survey has been developed to back the collection of information and assessment of

qualitative characteristics of some of the indicators. However, it is to be understood as supplementary information to that collected through desk-research methods. The HUBs will be responsible to join the results of the survey with their desk-research data and define the final scoring of each one of these indicators. The survey protocol for selected economic competencies indicators is available in the Guideline.

Once the indicator value or score has been determined, it should be reported in a ready-made template created for the HUBs to fill in. In addition to the information on the results, the sources that were used to develop it should also be indicated.

Biomass potential

The indicators will be assessed using a combination of quantitative and qualitative methods. Quantitative indicators, such as biomass yields, carbon footprints, and GVA, rely on statistical and geospatial data from national and international sources like FAOSTAT, Eurostat, and national statistical offices. These assessments involve calculations and normalizations (e.g., per hectare or tonne) to facilitate comparability across countries and regions.

Qualitative indicators, such as data availability and currentness will be assessed on an ordinal scale (e.g., low, medium, high). Experts will review the comprehensiveness, granularity, and accessibility of datasets and their alignment with the latest developments in biomass production and valorisation. This ensures that the assessment is not only data-driven but also critically reflective of the quality and reliability of the underlying data.

4 Outlook: Application and future steps for indicators assessment

For the implementation of the indicator framework by the HUBs, it is estimated a timeline of four months to complete the collection of supportive data and scoring of indicators. This timeline has begun with the presentation and explanation of the framework (December 2024), and preparations for the application of surveys (January 2025), specially the survey for the self-assessment of social competencies. For the technological and economic competencies, the survey is highly recommended to capture quality aspects, although of voluntary application.

Three main milestones have been established to follow-up the assessment of indicators in each country:

- Preparations ready for survey application (competences indicators) and beginning of desk research (January 2025).
- Desk research is completed and responses of surveys ongoing (January to February 2025).

- Finalization of the indicator scoring and presentation of results (templates) (March 2025).

Status report meetings on a monthly basis will be utilised to track the achievement of each of the milestones by the HUBs. Weekly Jour Fix meetings of voluntary attendance have been offered since the beginning of January 2025 until it's deemed necessary to provide a room for questions and clarifications.

Based on the established milestones and considering the required efforts to assess all indicators in the framework, results are expected by the end of April 2025. A documentation of all indicator results will be joined with the aggregated assessment expected from T3.3 in Deliverable 3.2, due in December 2025.

5 Conclusion

The development of the BOOST4BIOEAST indicator framework has provided a structured approach for assessing national readiness for the bioeconomy in CEE and Baltic countries. By integrating key dimensions – social, technological, economic competencies, and biomass potential – the framework offers a comprehensive tool for national HUBs to identify strengths, gaps, and opportunities in their bioeconomy landscapes.

The participatory process used to design and refine the indicators has ensured that they are relevant, feasible, and aligned with national and macro-regional needs. The testing phase, conducted in Slovakia, Romania, Hungary, and Latvia, played a crucial role in refining the methodology, improving the clarity of the assessment Guideline, and ensuring that the indicators can be effectively implemented across different national contexts. The decision to transition from expert interviews to structured surveys further enhanced the objectivity and comparability of the assessment.

The final indicator framework includes 29 competency indicators and 35 biomass potential indicators, providing a robust foundation for assessing and tracking progress toward bioeconomy development goals. The methodology outlined in this deliverable ensures that data collection is both systematic and adaptable, allowing HUBs to conduct consistent evaluations while accounting for country-specific nuances. The integration of both quantitative and qualitative indicators strengthens the capacity to measure bioeconomy readiness beyond simple economic metrics, incorporating aspects such as workforce skills, technological innovation, and environmental sustainability.

Looking ahead, the application of the indicator framework will support multiple strategic objectives within BOOST4BIOEAST. The results from the indicator assessments will directly inform national bioeconomy action plans, contribute to gap analyses, and provide critical

insights for policymakers. Furthermore, the structured methodology enables continuous monitoring and future refinements, ensuring that the framework remains relevant as the bioeconomy evolves.

The BOOST4BIOEAST indicator framework represents a significant advancement in the systematic assessment of bioeconomy readiness in the BIOEAST macro-region. By equipping national HUBs with the necessary tools and methodologies, it fosters data-driven decision-making and supports the transition toward a more sustainable, resilient, and competitive bioeconomy in the macro-region.

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7 Appendices

Appendix 1 – Template for reporting indicators

A template for reporting final values and scoring of indicators was created in Excel for the reporting of indicators results. This was provided to HUB Coordinators.

Available in BOOST4BIOEAST project SharePoint (partners only): https://biokutatas.sharepoint.com/:x:/r/sites/boost4bioeast/Shared%20Documents/WP3%20Enriching%20macro-regional%20and%20national%20knowledge%20on%20bioeconomy-related%20competencies%20and%20biomass/T3.1%20-T3.2%20documents/Indicators%20assessment%20framew.

It includes an introductory page with indications regarding the filling out of each indicator´s designated sheet and the criteria to evaluate data quality for all indicators. Likewise, the introductory page includes the indicator catalogue, with hyperlinks to each indicator´s sheet.

Introduction

Purpose of this document

This document is the reporting template for the BOOST4BIOEAST "Guideline for indicator assessment". Each indicator has a designated sheet, where the indicator assessment results should be recorded and sources as well as reasonings/proof stated. In addition to that, the data quality should also be reported according to the criteria below. The indicators are sorted by their competency (social, technological, economic). An overview is given below as well, and clicking on the name of the indicator will take you to the corresponding sheet.

Data quality criteria - How to identify information sources (e.g. data) that are of good quality?

Sources and data used for the assessment should be of good quality in order to provide valuble information. Below, three criterias are presented, that should be used to analyse the information quality. For each indicator that includes a desk research, there is a table on the according sheet that needs to be filled out according to the scoring (1-3).

Criterion	Meaning	Example questions, that help to assess criterion
Currency	Timelliness of the information	When was the information published? Has it been revised?
Reliability	The source of information	Who is the author, what are her/his credentials? Are there contact details given? Is the methodology given and complete?
Consistency	Data found is consistent and there are no contradictions among the findings	Is there any information found contrasting? Are the results mixed?

A sheet per indicator was created including a section to report its final value, share or score, sources consulted, and evaluated data quality criteria to evaluate quality of data utilized.

Examples of a reporting template for a qualitative as well as quantitative indicator are presented below.

Exemplary template for a qualitative indicator

S.1. Circular economy skills				
Scoring:				
1 = very low	**2 = low**	**3 = medium**	**4= high**	**5 = very high**
little to no knowledge, skills or experience regarding circular economy	limited knowledge or experience and guidance is needed to apply circular economy skills	people are familiar with circular economy skills, can apply those, but require occasional support; maybe there were a training or workshop	strong understanding and can apply circular economy skills independently with success.	highly skilled, regularly apply circular economy skills, people could train others in this area and work with stakeholders
Selected Score:				
Number of surveyed participants:		**Median:**		
		Standard deviation:		
Which public administration institutions were surveyed?				
List here all public administration institutions that were surveyed				
If applicable: Include consulted materials (e.g. reports, statistics)				
General feedback and suggestions.				
Please provide suggestions you might have for improving the indicator assessment process.				

Exemplary template for a quantitative indicator

T.3. Number of bioenergy and biorC3:E43efinery plants at national level (TRL 6 or higher)		
Assessment Results:		
Indicator	**Result**	**Date of assessment**
Number of bioenergy and biorefineries pilot and demonstration plants (TRL 6-7) as well as mature plants (TRL 8 -9) in the country in the last five years, and corresponding to the following categories:		
Bioenergy		
Biomethane		
Advanced liquid biofuels		
Biorefinieries		
Biochemicals		
Include consulted materials (e.g. reports, statistics)		

Please rate the quality of the data and sources used on the following scale (consult 'Introduction' for data

Currency	
Reliability	
Consistency	

Other comments regarding information quality:

If applicable: Survey details		
The survey was conducted? (yes/no)		
Total number of participants:		
Number of participants belonging to…		
R&D		
Universities		
Industry		

List here all bioeconomy sectors that were surveyed:

General feedback and suggestions:		

Please provide suggestions you might have for improving the indicator assessment process.

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Eesti Maaülikool Estonian University of Life Sciences

СЕЛСКОСТОПАНСКА АКАДЕМИЯ AGRICULTURAL ACADEMY

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APRE Agenzia per la Promozione della Ricerca Europea

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