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D2.4 - Report on the assessment of economic, environmental and social benefits

Maider Gómez and Paula de la Sen (CIRCE)

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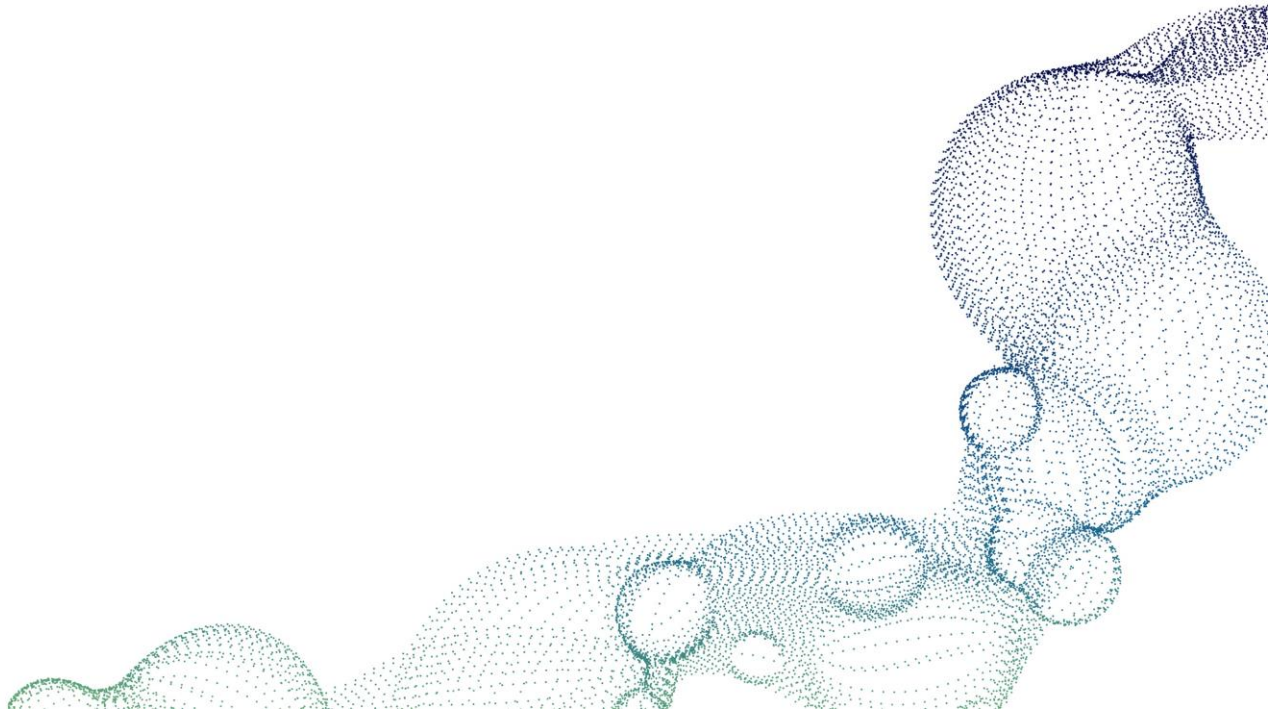

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1. INTRODUCTION

A well-developed bioeconomy can simultaneously drive sustainable development and address global challenges such as climate change, resource depletion or feeding a growing population. On the other hand, potential trade-offs must be managed to optimize outcomes. In this sense, the development and the promotion of the Bioeconomy Strategy is being one of the European Union (EU) priorities. The EU has established a comprehensive Bioeconomy Strategy aimed at promoting the sustainable use of biological resources to address societal challenges, drive economic growth, and ensure environmental protection. Initially adopted in 2012 and updated in 2018, the strategy aligns with broader EU policies, including the European Green Deal [1], the Circular Economy Action Plan [2], and the Farm to Fork Strategy and address key objectives such as ensuring food security, managing natural resources sustainably, reducing dependence on non-renewable resources, fostering a circular and low-carbon economy, mitigating and adapting to climate change and strengthening European Competitiveness and job creation. In June 2022, the European Commission published the Bioeconomy Strategy Progress Report, assessing the implementation of the 2018 strategy and its action plan. The report identified achievements, such as increased investment in bio-based industries and the development of national bioeconomy strategies by several member states. It also highlighted areas requiring further action, including the need for better integration of bioeconomy objectives into other policy areas and improved monitoring of environmental impacts.

Assessing the bioeconomy development requires a multi-dimensional analysis encompassing economic, environmental, and social benefits and costs. Efforts to measure these benefits typically employ indicators to monitor the current performance but also the impact of improvement measures carried out or to identify aspects that should be improved to boost bioeconomy promotion. [3].

Establishing a system based on monitoring indicators can significantly support the definition of the right strategy by identifying the most valuable initiatives and allocating resources to them, ensuring greater value generation. Moreover, it will enable an analysis of why certain projects failed to achieve the expected impact, fostering

necessary adjustments and improvements. In the specific case of BIOLOC, these indicators can contribute to the development of different project tasks. For instance, they can be instrumental in developing the roadmaps for each region, providing a mechanism to monitor whether the plans are delivering the desired effects and allowing for timely recalibrations or enabling the identification of the aspects that should be considered when developing the roadmap or strategy. Additionally, these indicators will be crucial for Task 4.3, where the objective is to propose value chains. Here, they can support the assessment of whether the regional context is suitable for replicating value chains and business models successfully implemented in other areas, ensuring effective and transferable outcomes.

This report, developed in the framework of T.2.4, aims to identify key indicators for the successful implementation of biobased systems from the economic, environmental, and social perspectives, serving as a foundation to assess the impact that regional biobased value chains could generate, particularly in revitalising local communities. Drawing on a detailed review of existing literature, insights gathered from workshops, and input from an expert panel, the report presents a selection of the most relevant indicators. This selection has been shared with regional representatives to gather additional feedback, ensuring that the final list of indicators is aligned with regional needs and priorities.

2. Methodology

Bioeconomy projects can generate impacts across different dimensions—social, economic, and environmental. For this reason, it is essential to evaluate these three pillars during the assessment process. This approach provides a comprehensive understanding of the potential impacts across multiple dimensions, making it applicable to strategies, individual projects, or regional development studies.

In this report, a methodology was developed to select and analyse indicators that reflect these three dimensions: **social** indicators evaluate how a project influences communities, equity, and quality of life; **environmental** indicators measure the project's effects on natural resources, ecosystems, and long-term sustainability; **economic**

indicators assess financial feasibility, efficiency, and the potential for economic growth. By integrating these three types of indicators, the methodology provides a comprehensive framework for assessing projects, demonstrating their economic viability, social inclusivity, and environmental sustainability. This holistic approach supports balanced and resilient development, aligning with the bioeconomy's overarching goals.

2.1. Main areas to evaluate social, environmental and economic

Once the importance of incorporating social, environmental, and economic indicators is understood, the next challenge lies in selecting the most relevant ones, especially given the extensive range of options available today and the research carried out focusing on this topic. This diversity reflects the variety of approaches and objectives when addressing sustainability and impact assessment. Each region and sector have unique characteristics influenced by factors such as local resources, infrastructure, and workforce availability, making some indicators more applicable than others depending on the specific context. Moreover, it is essential to ensure that the chosen indicators are backed by reliable and sufficient data, enabling not only temporal tracking within the same region but also meaningful cross-regional comparisons. By balancing local specificity with broader comparability, decision-makers can conduct evaluations that are both insightful and actionable.

In this context, several key aspects were considered to develop a comprehensive methodology for assessing the potential of the bioeconomy. First, understanding the availability and diversity of biological resources within the region is fundamental. This includes evaluating crops, forestry, livestock, aquatic resources, and biodiversity, considering not only their abundance and quality but also their sustainability and potential for value addition through bio-based processes. Additionally, existing infrastructure and technological capabilities play a critical role in supporting or constraining bioeconomy deployment. Infrastructure such as processing facilities, research institutions, transportation networks, and digital connectivity can act as drivers of growth or create barriers that must be overcome with targeted measures.

Access to financing is another crucial aspect, as financing opportunities significantly contribute to creating an enabling framework for bio-based initiatives. Assessing the financial landscape helps identify potential measures to enhance the current framework and attract investment. Furthermore, analysing market dynamics provides insights into the demand for bio-based products and services. This involves identifying market trends, consumer preferences, and niche opportunities, as well as evaluating the competitiveness of bio-based products compared to fossil-based alternatives.

Equally important is the policy framework, which shapes the regulatory and institutional environment for bioeconomy activities while recognising that this environment is also influenced by market dynamics, cultural phenomena, and broader socio-economic forces. Understanding existing barriers, incentives, and support mechanisms, along with the alignment of policy objectives with bioeconomy development goals, offers valuable insights for strategic planning. Lastly, socio-economic considerations are essential to ensure that bioeconomy initiatives foster inclusive development. This involves evaluating the impact on local communities, particularly in terms of employment opportunities, workforce skills, and potential barriers, to identify ways to maximise benefits while addressing challenges.

By integrating these dimensions—biological resources, infrastructure, financing, markets, policy, and socio-economic impacts into the evaluation process, policymakers can make more-informed decisions that maximize the potential of bio-based initiatives.

2.2. Literature review of key indicators

After defining the areas requiring monitoring, a comprehensive review of potential indicators based on the literature was performed. This process involved consulting a wide range of sources, such as scientific research papers and reports from relevant projects and reputable organisations, including the European Union, the Food and Agriculture Organization (FAO), and the Joint Research Centre (JRC).

These sources provided valuable insights into established methodologies and best practices for indicator selection. In addition to these external references, CIRCE

expertise from previous projects (public and private) was leveraged. This background knowledge enriched the approach, enabling CIRCE to incorporate lessons learned and refine methodologies from previous experiences. This cross-project insight supported the compilation of a robust preliminary list of indicators, ensuring their relevance and alignment with the defined monitoring areas.

2.3. Preliminary list of indicators

The following environmental indicators were selected based on the literature review:

TABLE 1. ENVIRONMENTAL PRE-SELECTED INDICATORS

Indicator	Description
Share of biomass side-streams, by-products, and waste used	Measures the extent to which these materials are purposed or reintegrated into production processes rather than discarded, reflecting resource-use efficiency and circularity.
No. of projects using feedstocks produced with sustainable practices	Tracks projects that use feedstocks generated with minimal environmental impact, contributing to zero pollution, climate change mitigation, and biodiversity enhancement.
No. of strategies and measures developed to reduce pollution in air, soil, and water	Serves as an indicator of targeted environmental interventions across various ecosystems.
Initiatives to improve resources' efficiency	Demonstrates efforts to optimise the use of water, energy, and other raw materials, ultimately aiming to reduce waste and improve the sustainability of operations.
No. of companies monitoring or enhancing the environmental performance of bio-based processes	Indicates the industry's commitment to reducing greenhouse gas emissions, optimizing resource use, and assessing social impacts, emphasizing transparency and responsibility.
No. of certification and standardisation bodies involved in bio-based production	Reflects the infrastructure in place to uphold environmental, social, and quality standards through recognized certifications and standards.
No. of regulations ensuring circularity and sustainability aspects	Illustrates policy and legislative backing for sustainable practices, encouraging compliance with principles like recycling, reuse, and environmental protection.

Following the literature review, the selected indicators for the social pillar are designed to assess various aspects of societal engagement, inclusivity, education, and workforce development in promoting the bioeconomy.

TABLE 2. SOCIAL PRE-SELECTED INDICATORS

Indicator	Description
No. of workshops/events promoting the bioeconomy and bio-based value chains	Reflects efforts to raise awareness and foster knowledge exchange among stakeholders (for instance, agreements).
No. of actions aimed at enhancing cross-disciplinary research and innovation activities	Highlights efforts to bridge various fields and encourage collaboration, which is crucial for advancing the bioeconomy.
No. of educational programs focusing on bioeconomy and bio-based valorisation technologies	Serves as an indicator of progress in knowledge development and capacity building.
No. of hubs, clusters, or entities to promote the bioeconomy and bio-based sector	Emphasises creating networks engaging multiple actors to foster cooperation and multi-level engagement.
No. of events or actions aimed at promoting social acceptance of bio-based products	Captures efforts to increase societal acceptance of bio-based products and initiatives.
No. of actions fostering interregional cooperative frameworks	Highlights efforts to support collaboration across regions, essential for unified bioeconomy development.
Socioeconomic indicators (e.g., high unemployment rate, urban population concentration)	It helps understand local challenges and the potential role of the bioeconomy in addressing them.
Share of the population with an educational degree	Indicates workforce quality, essential for developing a robust bioeconomy sector.
No. of Master Plans and strategies for promoting R&D	Reflects governance structures supporting research and the transition to alternative raw materials & CBE
No. of policies, strategies, or agendas supporting SDGs	Represents institutional support for transitioning to sustainable processes and alternative raw materials.
No. of associations representing socially marginal groups	Indicates inclusivity by highlighting organisations supporting marginalised groups.
No. of strategies and measures to integrate marginalised groups	Reflects administrative efforts to foster inclusivity and equal opportunities within the bioeconomy.

The preselection of economic indicators focuses on evaluating the sustainability of projects by identifying metrics that assess their economic viability.

TABLE 3. ECONOMIC PRE-SELECTED INDICATORS

Indicator	Description
No. of bio-based initiatives and/or innovative bio-based value chains	Demonstrates commitment to advancing efficient and modern production methods.
No. of bio-based products commercialised and their market share	Measures market acceptance and competitive positioning of bio-based products.
No. of measures aimed at enhancing market uptake of bio-based products	Highlights efforts to boost consumer demand and drive sustainable consumption.
No. of actions implemented to attract investment in the bio-based sector	Reflects efforts to create awareness and attract investment within the funding community.
No. of financing entities offering specific financing lines	Indicates the availability of tailored financial instruments for bio-based investments.
Availability of financing instruments (e.g., venture capital, equity funds, microfinancing)	Reflects the robustness of the financial ecosystem supporting bio-based projects.
No. of programs for initial investments in start-ups	Highlights support for emerging businesses, fostering innovation and growth in the bio-based industry.
No. of supporting institutions or advisory services	Ensures projects are well-prepared through business plan development, risk assessment, and investment securing.
No. of special taxation policies for bio-products	Provides fiscal incentives to encourage the production and adoption of sustainable bio-based solutions.
No. of bio-based initiatives and/or innovative bio-based value chains	Demonstrates commitment to advancing efficient and modern production methods.
No. of bio-based products commercialised and their market share	Measures market acceptance and competitive positioning of bio-based products.
No. of measures aimed at enhancing market uptake of bio-based products	Highlights efforts to boost consumer demand and drive sustainable consumption.

The preliminary list of indicators is summarised in Table 4.

TABLE 4. SUMMARY OF THE PRE-SELECTED INDICATORS

	INDICATOR
ENVIRONMENTAL	Share of biomass side-streams, by-products, and waste used
	No. of projects using feedstocks produced with sustainable practices
	No. of strategies and measures developed to reduce pollution in air, soil, and water
	Initiatives to improve resources' efficiency
	No. of companies monitoring/enhancing the environmental performance of CBE processes
	No. of certification and standardisation bodies involved in bio-based production
	No. of regulations ensuring circularity and sustainability aspects
SOCIAL	No. of workshops or events conducted to promote CBE and bio-based value chains
	No. of actions aimed at enhancing cross-disciplinary research and innovation activities
	No. of educational programs on bioeconomy and bio-based valorisation technologies
	No. of hubs, clusters, or entities to promote the bioeconomy and bio-based sector
	No. of events or actions aimed at promoting social acceptance of bio-based products
	No. of actions fostering interregional cooperative frameworks
	Socioeconomic indicators (e.g., high unemployment rate, urban population concentration)
	Share of the population with an educational degree
	No. of Master Plans and strategies for promoting research and development
	No. of policies, strategies, or agendas supporting sustainable development goals
	No. of associations representing socially marginal groups
	No. of strategies and measures to integrate marginalised groups
	No. of private sector initiatives to include marginalised groups in bio-based value chains
ECONOMIC	No. of bio-based initiatives and/or innovative bio-based value chains
	No. of bio-based products commercialised and their market share.
	No. of measures aimed at enhancing market uptake of bio-based products
	No. of actions implemented to attract investment in the bio-based sector
	No. of financing entities offering specific financing lines
	Availability of financing instruments (e.g., venture capital, equity funds, microfinancing)
	No. of programs for initial investments in start-ups
	No. of supporting institutions or advisory services
	No. of special taxation policies for bio-products

The indicators listed above are intended to be meaningful indicators for any country in Europe. No specific indicators have been identified, but rather general concepts, as concrete and specific national conditions and frameworks, should be considered to adapt these indicators into specific, quantifiable metrics. This process should be carried out by ensuring that the indicators are aligned with specific objectives and by identifying the specific aspects of the indicator that can be quantified. In addition, validation tools or metrics should be provided to confirm that achievements and improvements have been made.

In addition, it should be emphasised that the indicators for the development of the bioeconomy are linked to the level of readiness of society and that this relationship is constantly changing. For example, the affordability of bio-based solutions for individuals and businesses, or the willingness to invest in bioeconomy initiatives, will affect the overall development of the bioeconomy in the region or country. In addition, the successful implementation of bioeconomy solutions will help to strengthen societal readiness by increasing trust and awareness, while policy incentives and education programmes can accelerate both societal readiness and bioeconomy development.

2.4. Regional relevance of preselected indicators

The list of preselected indicators was shared with the regional partners with the aim of retrieving information regarding which indicators of each category are the most relevant considering the specific condition of each region. The results of this consultation can be found in Annex 1. The outcome was a list of 10 indicators: 3 with an environmental focus, 3 with a social focus and 4 with an economic focus. This list was subsequently analysed using the AHP methodology with the help of a panel of experts.

- **ENVIRONMENTAL INDICATORS:**
  a) *Share of biomass side-streams, by-products, and waste that is used*
  b) *No. Of strategies and measures seeking to improve resources' efficiency*
  c) *No. of regulations to ensure that circularity and environmental aspects are considered*

- **SOCIAL INDICATORS:**
  - d) *No. Of hubs, clusters or other entities or initiatives seeking to promote bioeconomy and bio-based sector addressing multi-level actor interactions (e.g. private stakeholders, policymakers, financing actors/institutions, media, social marginal groups representatives, etc.)*
  - e) *No. of policies, strategies or agendas for supporting the transition to alternative raw materials use, circular economy, biobased economy or sustainable processes*
  - f) *No. of strategies and measures developed by the administration to integrate socially marginal groups*
- **ECONOMIC INDICATORS:**
  - g) *No. of bio-based initiatives (industries, projects, start-ups, etc.) and/or innovative bio-based value chains created or ongoing*
  - h) *No. of bio-based products commercialised*
  - i) *No. of financing entities with specific financing lines for direct or intermediate investment in the bio-based sector*
  - j) *Jobs generated in the bioeconomy sector*

2.5. Analytic Hierarchy Process (AHP)

The methodology considered to establish the relevance of the different Key Indicators was the Analytic Hierarchy Process (AHP). The AHP is a structured decision-making methodology developed by Thomas Saaty, widely used to prioritise and make decisions in complex situations involving multiple criteria and alternatives [4]. The first step in the AHP methodology is to structure the decision problem into a hierarchical model. The criteria represent the different factors that are important for the decision. The decision-makers, in this case, the expert panel consulted, are asked to make pairwise comparisons between the criteria based on their relative importance or preference. The comparisons are typically made using a numerical scale, such as Saaty's 1-9 scale, where 1 represents equal importance, and 9 represents extreme importance. Decision-makers compare each element against every other element at the same level of the hierarchy. After completing the pairwise comparisons, AHP calculates consistency ratios to assess the consistency of the judgments made by the decision-

maker. Consistency is important to ensure the reliability of the results. Therefore, when the consistency ratio exceeded a predefined threshold (usually 0.1), the decision-maker was asked to review and revise their judgments to improve consistency supported by CIRCE. The 10 criteria evaluated are depicted in Table 5.

TABLE 5. CRITERIA CONSIDERED IN THE AHP METHODOLOGY

CRIT-1	Share of biomass side-streams, by-products and waste that are used
CRIT-2	No. of strategies and measures developed seeking to improve resources' efficiency.
CRIT-3	No. of regulations to ensure that circularity and environmental aspects are considered.
CRIT-4	No. of hubs, clusters or other entities or initiatives seeking to promote bioeconomy and bio-based sector addressing multi-level actor interactions (e.g. private stakeholders, policymakers, financing actors/institutions, media, social marginal groups representatives, etc.).
CRIT-5	No. of policies, strategies or agendas for supporting the transition to alternative raw materials use circular economy, biobased economy or sustainable processes.
CRIT-6	No. of strategies and measures developed by the administration to integrate socially marginal groups.
CRIT-7	No. of bio-based initiatives (industries, projects, start-ups, etc.) and/or innovative bio-based value chains created or ongoing
CRIT-8	No. of bio-based products commercialised.
CRIT-9	No. of financing entities with specific financing lines for direct or intermediated investment in the bio-based sector
CRIT-10	Jobs generated in the bioeconomy sector

Once the pairwise comparisons were completed and consistency was checked, priority scores for each criterion were calculated. These priority scores represent the relative importance of each element in the hierarchy. Priority scores are calculated using eigenvector methods based on the pairwise comparison judgments.

Overall, the AHP methodology provides a systematic and structured approach to decision-making, helping decision-makers handle complex problems involving multiple criteria. This method relies significantly on the expert panel that provided the evaluation of the indicators. For this aim, technical and regional partners were asked to provide contact of experts within the bioeconomy field and form an expert panel. These experts were asked to rank the indicators using an Excel sheet prepared by CIRCE according to the AHP methodology. The outcome obtained from the different experts yielded the priority scores (weighting factors), which should be considered when assessing the current state of the bioeconomy.

3. RANKING OF KEY INDICATORS

Results were obtained once all the answers from the consulted experts were compiled. Firstly, the general results, considering the priority scores from all the consulted experts together, can be seen in Figure 1. This figure illustrates the percentage-based prioritisation of key criteria/indicators determined by the experts. Each segment is labelled with the number corresponding to the specific criterion, while a detailed description of each indicator can be found in **Errore. L'origine riferimento non è stata trovata.**

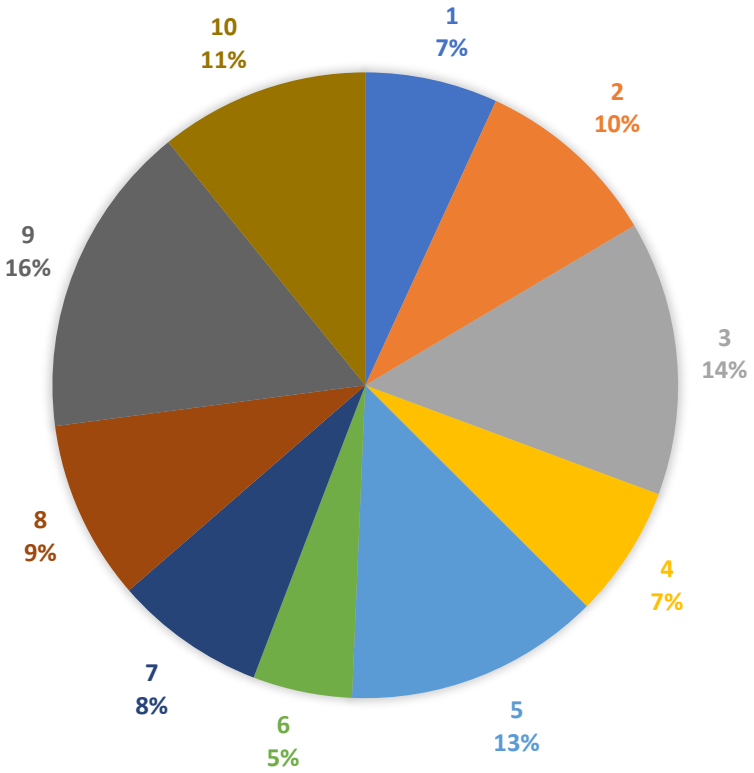


FIGURE 1

Considering the perspective of all the experts consulted, the ranking highlights key priorities and more relevant areas for improvement when assessing the development of the region's bioeconomy. Among the most valued indicators, the availability of specific financing lines for the bio-based sector (16.3%), followed by regulations ensuring

circularity and environmental aspects (14.2%), and strategies supporting the transition to sustainable processes (13.2%) stand out. These results strongly emphasise structured policies and financial mechanisms as the foundation for bioeconomy growth. In contrast, indicators related to social integration strategies (5.1%), multi-actor hubs or initiatives (6.8%), and the use of biomass side streams and by-products (6.9%) are perceived as less critical. This suggests that social inclusion and collaboration networks are not as essential as regulations, policies, and financing for driving the bioeconomy forward.

The results also show a prioritisation of structural factors, such as policies and funding, over market aspects like the commercialisation of bio-based products (9.3%) and employment generation (10.8%). Similarly, innovation and collaboration efforts, such as bio-based initiatives (7.8%) and hubs fostering multi-stakeholder interaction (6.8%), hold moderate importance but are overshadowed by regulatory and financial drivers. These findings underline the critical role of robust regulatory frameworks and targeted financial support in accelerating bioeconomy development. However, they also reveal significant opportunities to enhance social inclusion and strengthen multi-stakeholder collaboration. Promoting these aspects could contribute to ensuring a more holistic and sustainable growth of the bioeconomy. Future efforts should aim to integrate social, environmental, and economic dimensions more effectively, balancing structural advancements with inclusive and collaborative practices.

On the other hand, an analysis has also been made, unifying the results by the expertise of each expert, to see how the results vary:

- Figure 2 shows the answers of R&D experts;
- Figure 3 depicts the viewpoint of bioeconomy hub members;
- Figure 4 accounts for the perspective of civil society representatives;
- Figure 5 shows the answers of primary sector cooperative members.

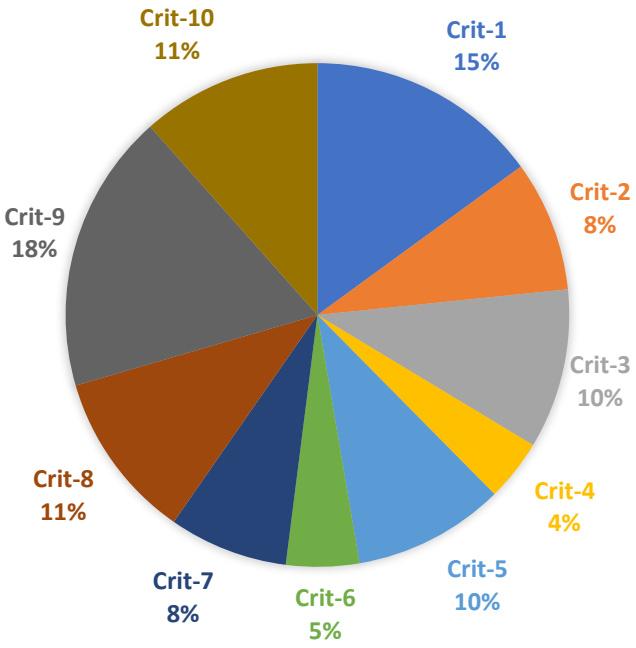


FIGURE 2

For the consulted experts whose background is related to the R&D sector, the most valued indicators are the number of financing entities with specific lines for the bio-based sector (18%) and the use of biomass by-products and waste (15%), followed by the number of jobs generated (11.6%) and the commercialisation of bio-based products (10.8%). This, as shown in Figure 2, reflects a technical and economic focus on financial support and efficient use of resources, which are essential to advance the bioeconomy from an innovative perspective.

In contrast, bioeconomy hub members prioritise the commercialisation of bio-based products (23.8%), specific financing lines (14.9%), and regulations for circularity and environmental sustainability (12%). This suggests a market-oriented perspective where economic viability, product development, and financial accessibility are seen as central to fostering a thriving bioeconomy ecosystem (Figure 3).

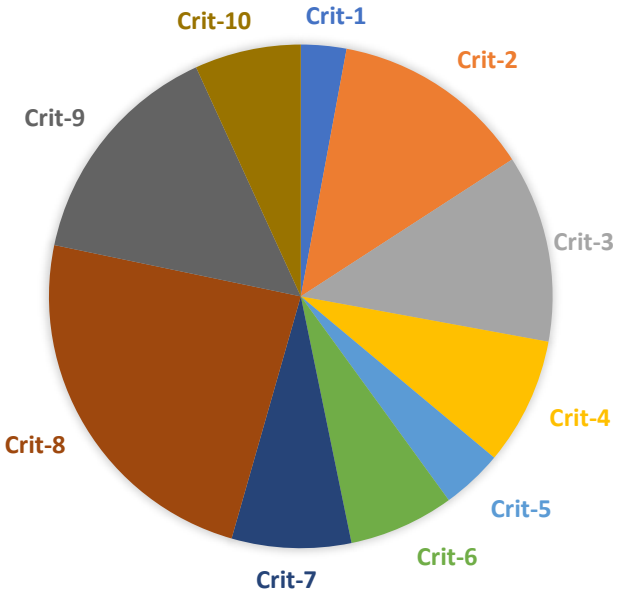


FIGURE 3

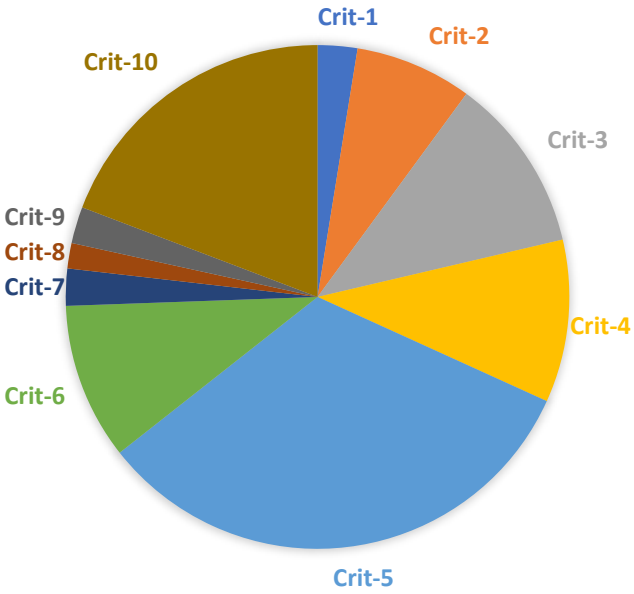
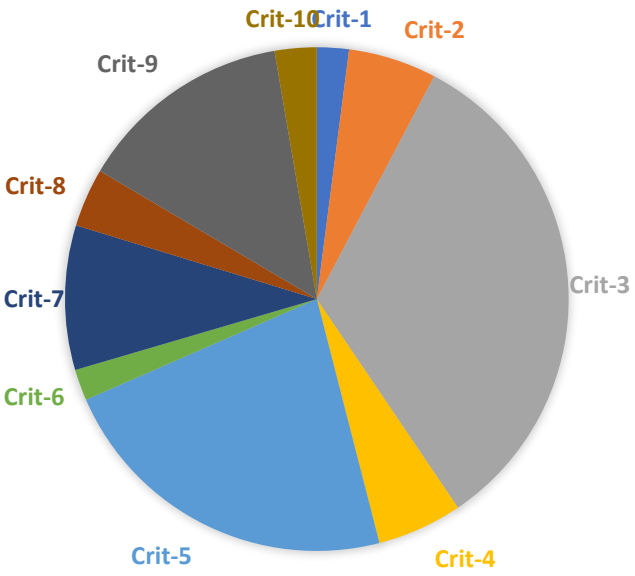


FIGURE 4

Otherwise, the perspective of the experts from a social entity shown in Figure 4 they place the highest importance on policies and strategies supporting the transition to alternative raw materials and sustainable processes (32.6%), followed by employment generation in the bioeconomy sector (19.2%) and the development of regulations ensuring circularity and environmental protection (11.3%). This group highlights the need for inclusive policies and frameworks to achieve sustainable transitions, with a particular focus on social impacts like job creation as a core measure to reach successful deployment of the bioeconomy.

For agricultural cooperative members (Figure 5), environmental regulations (32.8%) and policies supporting the bioeconomy (22.5%) are of the utmost importance, followed by access to specific financing (13.8%). These results indicate a strong emphasis on regulatory frameworks and strategic support for transitioning to sustainable agricultural practices. However, aspects such as employment generation (2.7%) and social inclusion (2%) are given less importance, reflecting a focus more on structural and operational factors rather than social impacts.

FIGURE 5



The differences across groups highlight contrasting perspectives. R&D experts and hub members focus heavily on economic drivers like financing and market development, essential for implementing projects and advancing bio-based product commercialisation. In contrast, social identity experts emphasise inclusive policies and employment generation, reflecting their concern for the societal benefits of bioeconomic progress. Agricultural cooperatives, meanwhile, prioritise regulatory support and policy-driven transitions, which align with their reliance on structured frameworks for adopting sustainable agricultural practices.

These variations can be attributed to the distinct roles and interests of each group within the bioeconomy ecosystem. Regulatory considerations are more critical for agricultural cooperatives due to their direct involvement with environmental policies, while hubs and R&D experts lean towards economic and technological factors that ensure the viability and scalability of bioeconomic initiatives. Social inclusion strategies receive consistently lower importance across groups, suggesting that this dimension is not yet widely recognized as a strategic priority.

In conclusion, these differences underscore the need to integrate the diverse perspectives of stakeholders in shaping a balanced bioeconomy. By aligning the technical, economic, social, and regulatory dimensions, a more holistic approach can be developed to address sustainability, inclusivity, and economic growth in the bio-based sector. In the specific context of BIOLOC, the selected indicators can play a key role in monitoring the project's main objectives, such as fostering the development of a sustainable bioeconomy in the regions where it is implemented. Additionally, BIOLOC stands out for its emphasis on social impact, reflected in the inclusion of indicators such as the number of hubs promoting bioeconomy collaboration and the strategies designed to integrate socially marginalized groups. This approach ensures that BIOLOC not only advances economic and environmental goals but also contributes to inclusivity and the creation of resilient, socially equitable communities.

4. CONCLUSIONS

The conclusions of Deliverable 2.4 emphasize the central role of indicators in assessing progress in the bioeconomy deployment. Indicators can play a key role when evaluating economic, social, and environmental dimensions, providing a clear framework for measuring advancements and supporting informed decision-making. Their careful selection is critical, as it determines the reliability and relevance of the assessment. In this deliverable, the process of identifying indicators was grounded in both a thorough literature review and a practical understanding of regional contexts. Factors such as the specific conditions of each region, data availability, and the need for cross-regional comparability were key considerations.

These indicators enable the strategic allocation of efforts and resources toward bio-based value chains that deliver the greatest impact. In a field like the bioeconomy, where resources are inherently limited, this alignment is vital for fostering sustainable development. By prioritising initiatives that maximise environmental benefits, economic growth, and social inclusion, regions can achieve greater resource efficiency and resilience, forging a robust bioeconomy.

Furthermore, the selected indicators align with the principles of the Social Readiness Level (SRL) framework, particularly in addressing societal acceptance, inclusivity, and institutional preparedness. Indicators such as the number of hubs fostering collaboration and the strategies aimed at integrating marginalised groups directly contribute to assessing and enhancing the SRL of bioeconomy initiatives. This ensures that projects are not only technically and economically viable but also socially sustainable and embraced by the communities they aim to benefit.

The results of this study reveal notable insights into stakeholder priorities. Overall, there is a consensus on the importance of financial support mechanisms and regulatory frameworks, as reflected in the high prioritisation of indicators such as financing entities specific to bio-based sectors and policies supporting circularity. However, differences emerge across areas of expertise. For example, R&D experts emphasised resource efficiency and financing, while agricultural cooperatives prioritised regulatory

support for sustainable transitions. These variations underscore the diverse perspectives within the bioeconomy ecosystem, highlighting the need for tailored approaches to address specific regional and sectoral needs.

In conclusion, the adoption of well-chosen indicators is essential for guiding sustainable bioeconomy development monitoring. They not only provide a foundation for monitoring progress but also ensure that limited resources are directed toward the most impactful framework aspects and value chains, contributing to long-term regional and environmental sustainability and resilience. Additionally, by incorporating dimensions aligned with the SRL, these indicators strengthen the capacity of bioeconomy projects to achieve broader societal acceptance and inclusion, which are key to ensuring their long-term success and impact.

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ANNEX 1: FEEDBACK RECEIVED FROM THE REGIONAL PARTNERS REGARDING THE PRE-SELECTION OF INDICATOR

	IT	CZ	RO	SK	SI	DE	ES	NL	EL	HR	BG	HU
No. of workshops or events performed targeting bioeconomy and bio-based value chain promotion.												
No. of actions to improve the intensity of cross-disciplinary research and innovation activities.											10	
No. of educational programs focusing on bioeconomy and bio-based valorisation technologies.											3	
No. of hubs, clusters or other initiatives promoting CBE by addressing multi-level actor interactions (e.g. private stakeholders, policymakers, financing actors/institutions, media, social marginal groups representatives, etc.).												
No. of events or actions to increase social acceptance of bio-based products/initiatives.											3	
No. of actions contributing to fostering interregional cooperative framework.											4	
High unemployment rate (over 9%)												
Population concentrated in urban areas												
Quality of workforce: Share of population if an educational degree												
No. of Master Plans/Strategies for R&D promotion											1	
No. of social marginal groups representative associations.											5	
No. of policies, strategies or agendas for supporting the transition to alternative raw materials use, circular economy, biobased economy or sustainable processes.											3	
No. of strategies and measures developed by the administration to integrate socially marginalised groups.											2	
No. of private sector initiatives to integrate socially marginalised groups.												
No. of private sector initiatives to integrate socially marginalised groups in CBE value chains.												

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	IT	CZ	RO	SK	SI	DE	ES	NL	EL	HR	BG	HU
Share of biomass side-streams, by-products and waste that are used												
No. of projects using feedstocks generated with practices that contribute to zero pollution, climate change mitigation, enhanced biodiversity												
No. of strategies and measures developed seeking to contribute to reducing air, soil and water pollution.												
No. of strategies and measures developed seeking to improve resources' efficiency.												
No. of companies addressing or monitoring environmental (GHG emissions decrease, resources' efficiency, social impact, etc.) performance of their bio-based process.											8	
No. of certification and standardization bodies.											9	
No. of regulations to ensure that circularity and environmental aspects are considered.												

	IT	CZ	RO	SK	SI	DE	ES	NL	EL	HR	BG	HU
No. of bio-based initiatives (industries, projects, start-ups, etc.) and/or innovative bio-based value chains created or ongoing	■	■	■	■	■	■	■	■	■	■	■	
Existing measures to facilitate the deployment of innovative production technologies	■		■	■	■	■	■	■	■	■	■	
No. of bio-based products commercialized	■		■	■	■	■	■	■	■	■	■	
Market share of bio-based products in the country/region	■			■	■	■	■				■	
No. of measures to facilitate market uptake of bio-based products	■		■	■	■	■	■	■	■		■	■
No. of actions implemented to attract investment and/or to create awareness in the investment/funding community	■		■	■	■	■	■		■	■	■	■
No. of financing entities with specific financing lines for direct or intermediated investment in bio-based sector	■	■	■	■	■	■	■		■	■	■	
Availability of financing instruments such as venture capital, investment equity funds or microfinancing	■	■		■	■	■	■		■	■	■	
Specific programs for initial investments for start-ups	■	■	■	■	■	■	■		■	■	■	
Available supporting institution or advisory service for business plan development, risk assessment and looking investments in new industrial, sustainable project	■	■	■	■	■	■	■		■	■	9	■
Special taxation for bio-products	■			■	■		■		■		■	
Jobs generated by bioeconomy												