BioINSouth

Supporting regional environmental sustainability assessment for the BIO-based sectors to improve INnovation, INdustries and INclusivity in SOUTH Europe

Deliverable 4.1
Monitoring System

- Cyprus
- Czech Republic
- France
- Greece
- Portugal
- Italy
- Slovenia
- Spain
- Türkyie

Bio-based Industries Consortium

Circular Bio-based Europe Joint Undertaking

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Supporting regional environmental sustainability assessment for the BIO-based sectors to improve INnovation, INdustries and INclusivity in SOUTH Europe

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1 Introduction

Circular economy (CE) is a model of production and consumption where cleaner and more competitive practices focus on saving and recovering resources[1]. However, the principles of the circular economy have been expressed in many ways depending on the point of view[2] and limited monitoring initiatives exist to assess bio-based product systems.

On the one hand, technical cycles involve the management of non-renewable stocks of abiotic resources and materials flows that cannot be adequately returned to the biosphere. Increasing circularity in the chemical value chain implies that secondary material is reused/recycled, which means that also those processes (e.g., recycling of chemicals) should be integrated in the chemical's life cycle [3].On the other hand, in biocycles, products are designed with the intention to be consumed or used in cascade and subsequently decomposed to re-enter the biosphere. Biological cycles contain the flows of renewable biotic resources that can safely cycle in and out of the biosphere[4] (see *Figure 1*).

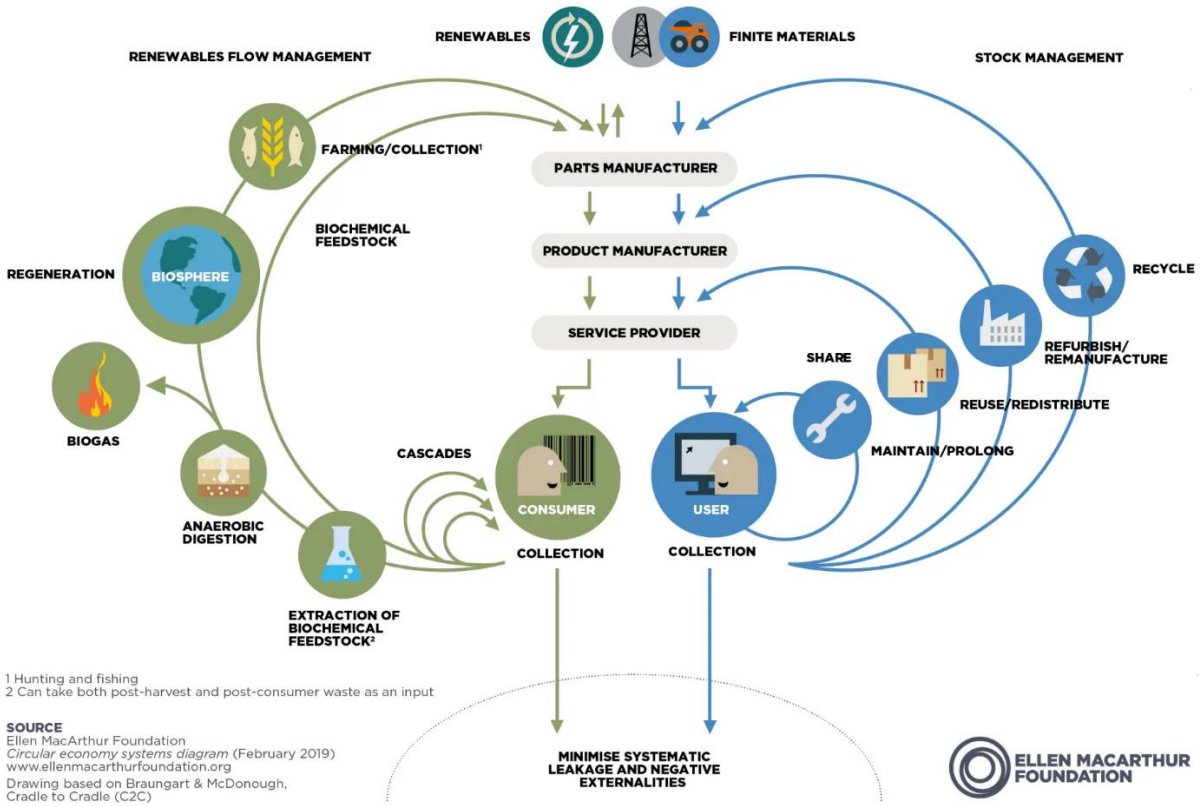

Figure 1 biological and technical cycles within the circular economy

Bioeconomy faces several challenges, such as incorporating innovations, scaling up biotechnologies and bioprocesses to drive de-fossilisation and integrating resource-efficient process that provide more value from less resources. A regenerative and sustainable bioeconomy is also mandatory within the planetary boundaries. In this context, it is of relevance the development of methodologies to measure the circularity embedded in bio-based products[5] and to enable comparison between products of the same type or category. However, renewability, organic content and cascading are the principal attributes of bio-based products that make it difficult to apply methodologies applicable to technical cycles. Given those limitations, many different approaches and CE indicators have been proposed in literature and there is

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no agreement regarding the most appropriate framework for measuring the performance of the bioeconomy[6,7]. Linder et al[8]. compared different product-level circularity metrics, concluding that none of the existing initiatives scored highly across the criteria of validity, reliability, transparency, and generality. As part of the metric studied by Linder et al, the Material Circularity Indicator (MCI) was identified as an appropriate approach for the evaluation of product circularity. Although the revised version (2019) included biological cycles, the MCI was originally developed to measure the circularity of technical products [9].

BioINSouth project develops regional HUBs to promote and implement bio-based economy strategies within the Southern European regions. Given the relevance of incorporating sustainability considerations into these regional economy roadmaps, BioINSouth aims to develop a monitoring system to quantify the environmental (Task 4.2) and circularity performance (Task 4.5) of the HUBs actions.

The present deliverable entails the methodological context and framework to define a circularity monitoring system for European southern regions which will support the adoption of activities without exceeding the ecological limits. With the objective of developing a robust methodology, application and challenges of different initiatives for circularity assessment have been explored. The biobased aspects which have been most highlighted in the circularity assessment initiatives have been also identified. In conclusion, a comprehensive overview of trends, advancements and challenges have allowed to define a framework considering the applicability, feasibility and scalability of the monitoring system.

2 Circularity performance of the bioeconomy

Circularity performance has different meanings depending on the perspective from which it is evaluated. Keeping in mind the essential concept embedded in the circular economy definition, circularity performance should evaluate to which extend the system is successful in maintaining circular flows of resources, by recovering, retaining or adding value.

Following the premise that “what gets measured gets managed”[8], the evaluation of circularity provide useful information to manage and maximize the sustainability of the bioeconomy. In the manner it operates at various levels, circularity is measurable through indicators also at different scales. Some authors identify the macro-scale[10,11] as the level relates to cities, regions, countries and beyond; the meso-scale relates to industrial synergies and micro-scale level relates to products, services or companies.

As conclude in many of reviewed texts, and very well summarised by Vural at al[6], existing metrics provide a good coverage of the aspects of resource flows, efficiency, recirculation, but most of them have limitations to cover the characteristics of the bio-based systems.

With a focus on biomass and bioresources use at both scales, industrial and product level, several indicators have been defined in literature to monitor the efficiency in the use of this biomass[12], whether for production, conversion or minimisation. All approaches focus the assessment on the biomass with bio-industrial application. Highlighting the most interesting indicators gathered by Mesa et. al[12], Biomass Utilisation Factor aims to evaluate the degree and frequency of biomass use following a mass balance methodology, while Biomass Utilization Efficiency indicator focuses on the conversion efficiency of biomass into products, by measuring the percentage of biomass that ends up in the final bio-product.

With a particular focus on forestry biomass, the cascading factor indicator allows the analysis and quantification of the flow and use of wood resources, emphasising the concept of cascading[13]. This approach implies a detailed analysis of wood flows, incorporating resource monitoring, conversion factors and a bottom-up approach, which ensures an accurate assessment of wood use at each stage of the life

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cycle. With a sector approach Jander[14] suggests methodologies including the accountability of carbon cycles[14] for measuring the circularity performance of bioplastics.

Not sector specific, but initially designed for technical cycles, the Material circularity Indicator developed by the Ellen MacArthur Foundation in 2015[15] aims to assist companies in measuring the circularity of their products, components, or materials under a life cycle perspective. MCI not only informs on the extent to which a product is made from recycled or reused materials but also how much of its material can be recycled or reused at the end of its life.

Also targeting companies, Bioresources Utilization Index (BUind) [16] assesses the efficiency of bioresource utilization informing on how effectively a company uses its incoming resources and manages by-products. Together with quantifying, the index helps companies on identifying key areas for improvement in bioresources management.

With a broader approach, integrated assessment approaches suggest the relevance of incorporating not only environmental, but also social and economic indicators as part of the metrics. Sustainability assessment of the bioeconomy helps to identify the alignment of the circular economy with the Sustainable Development Goals, SDG, but it may not facilitate the focus on the performance at resources flows level. Nevertheless, the relevance of evaluating the complete sustainability profile of any process or product within the bioeconomy is essential to ensure that the new bio-based models are real drivers for a sustainable development.

3 Circularity monitoring initiatives

This section summarizes the most relevant initiatives that monitor diverse aspects embedded in the circular economy, under different angles and scales.

CIRCULAR ECONOMY MONITORING FRAMEWORK[1]

At European level, Eurostat provides an overview of the efforts to transition from linear to circular economy through the Circular Economy Monitoring Framework. Eurostat makes data available through databases that presents macro-level statistics not only useful for environmental aspects, but also for economic and social analysis (Figure 2). Indicators related to material use, waste, recycling rates or resource use are provided to guide policymakers and facilitate cross-country comparisons.

Figure 2 Indicators within the Circular Economy Monitoring Framework (source: Eustat)

CIRCULARITY METRICS LAB[2]

[1] https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework
[2] https://www.thecircularlab.com/

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Lead by the European Environment Agency, The Circularity Metrics Lab is an initiative that aims to advance the measurement and understanding of circular economy performance in Europe. It is focused on environmental data, tracking resource flows and waste management related to the circular economy. With own specific methodologies, the EEA follow the principles of the Material Flow Analysis, input-output Analysis and recommendations form the Life cycle assessment (LCA) to measure circular economy progress.

Both, EEA and Eurostat play a significant role in the transition toward circular economy. However, while Eurostat, with a broader scope, is primarily responsible for statical data collection and provides harmonized statistics, EEA focused more on environmental data and how EU countries manage their environmental impacts.

CIRCULAR BENCHMARK TOOL[3]

With a focus on benchmarking for organisation, the circular benchmarking tool helps industries to evaluate how they perform in terms of product life cycle management, resource efficiency and waste reduction. By identifying opportunities for improvement, with CBT companies can obtain insights to drive efforts to reduce the environmental footprint while being aligned with circular economy principles. Interested companies need to set up a user profile to access to the 6 indicators that can be visualized in a PDF report. Except for the "Explore and Trial" account, CBT implies different pricing depending on the level of membership types.

CIRCULAR CITIES AND REGIONS

The Circular Cities and Regions initiative (CCRI) is a Multi–stakeholder Collaboration & Support Scheme (Figure 3) that aims at progressing on the circular economy at local and regional levels. It was launched in 2023 to collaborate with cities and regions in developing innovative initiatives by providing financial and technical support. In this context the CCRI helps cities and regions to implement circular solutions with focus on achieving the EU Green Deal climate neutrality goals.

[3] https://circularbenchmarktool.eu/

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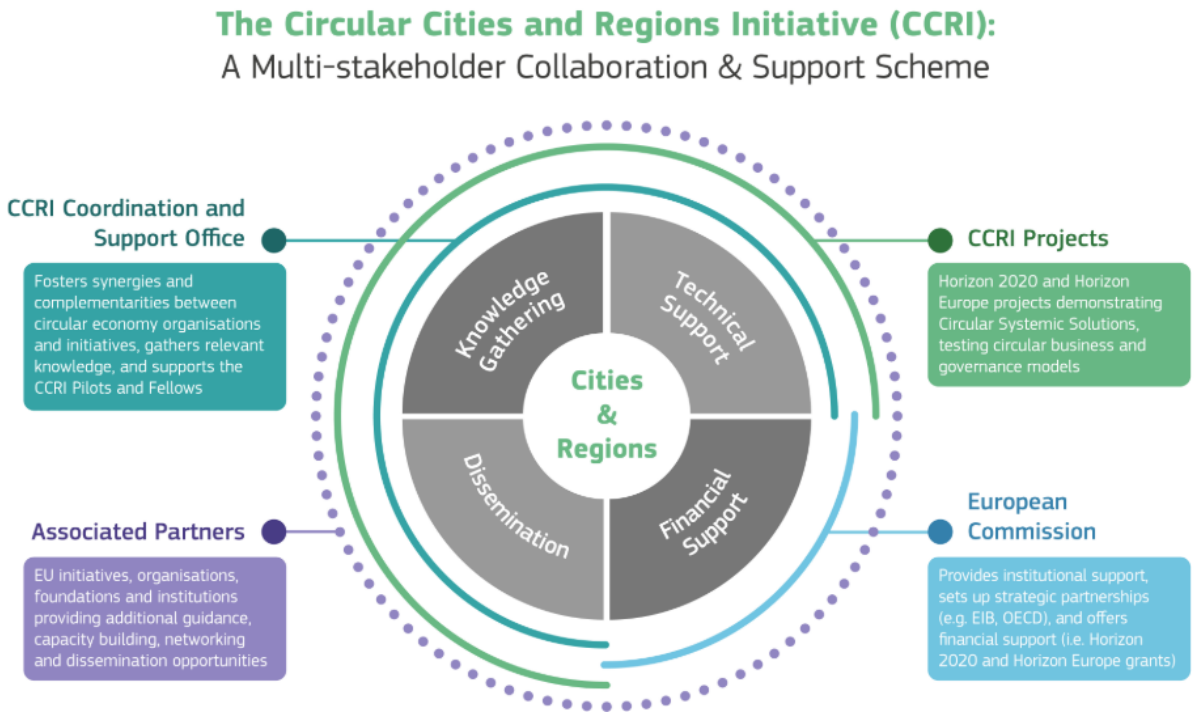

Figure 3 CCRI framework (source: https://circular-cities-and-regions.ec.europa.eu/about)

For the monitoring and the evaluation of the transition towards a circular economy, the CCRI has developed a self-assessment tool which assist cities and regions in defining specific goals while allow them the tracking of progress through specific indicators. The tool is being currently proved in a testing period, but preliminary information reveals that the indicators will cover the essential parts of the environmental protection.

SUSTAINABLE BY DESIGN FRAMEWORK

The European Commission Decision established a framework[4] for evaluating chemicals and materials as 'safe and sustainable by design'. It outlines criteria to ensure that substances are designed to minimise harm to health and the environment. This framework aims to promote sustainable innovation and the circular economy, while safeguarding human and environmental well-being (Figure 4).

With respect to the measurement of circularity, common metrics often focus on aspects linked to either material efficiencies (e.g., percentage of materials outflow compared to inflow) or recyclability (e.g., percentage of recycled content in a product, recycling efficiencies etc.). This framework provides the revision of indicators commonly used in studies. The revision highlighted that recyclability was the most relevant aspect covered for the circularity of chemicals. However, the reviewed studies did not suggest or recommend any method or metric. Secondly, the recycled content was identified as other aspect usually covered. The percentage of recycled content in products can be potentially used as a metric of circularity for chemical and products that may content chemicals[3].

[4] C (2022) 8854 final of 8 December 2022

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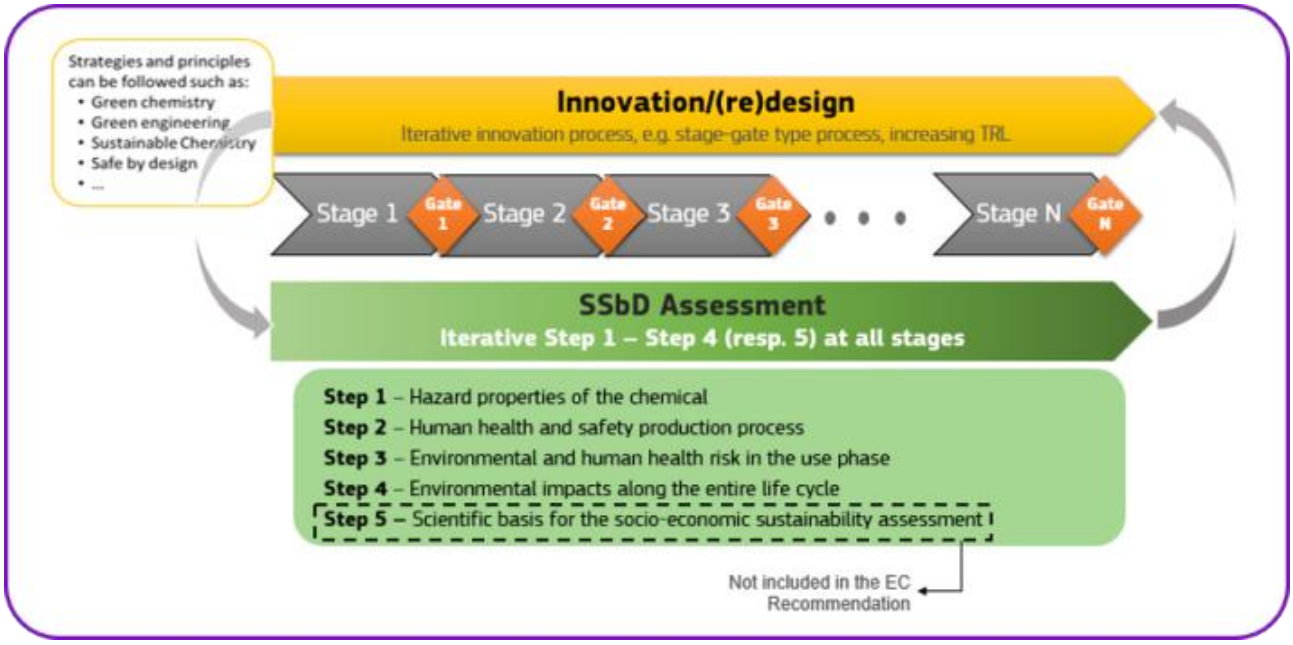

Figure 4 SSBD framework, (source[18])

The project addresses partially aspects of the SSBD, such as the environmental impact, as part of task 4.2. however, the circularity aspects covered by the SSBB are limited to meet BioINSouth monitoring objectives. Once the complete methodology has been published (2024), it can be demonstrated that the BioINSouth project does not meet the structure for the full implementation of an SSBD framework, as the project does not develop either design specific processes or products. BioINSouth aims to promote the innovation through the promotion of bioeconomy strategies, but it does not deal with the innovation stages stablished in the JRC framework.

4 Circularity monitoring in EU projects

In line with the approach taken in the Environmental Assessment task, circularity monitoring of BioINSouth started with the identification of key ongoing projects, which are evaluating circularity at different levels, and for diverse purposes.

Table 1 Reference list of ongoing projects related to circularity monitoring

Project	Project objective	Sectors covered	Countries
BIORECER	To promote the use of biological feedstocks as raw materials.	Fishery Urban Biowaste Agriculture Forestry	Spain Italy Greece Sweden
BIOTRANSFORM	To provide a development plan to accelerate the transition to circular bio-based systems.	Forestry Agri-food Lignite and minerals Chemicals	Austria, Czech Republic, Finland, Germany, Greece, and Spain
C4B	To develop and promote innovative and sustainable business models.	Agriculture Forestry	Germany Italy Greece

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Project	Project objective	Sectors covered	Countries
			Sweden Austria Switzerland
CALIMERO	To create a common framework to improve existing LCA methodologies.	Construction Woodworking Textile Pulp & paper Biochemicals	France Belgium Spain Sweden
ESCIB	To develop a new methodology for bio-based systems sustainability assessment.	Packaging Textiles Chemicals Construction	Portugal, among others
LCA4BIO	To develop methodologies for environmental assessment and circularity.	Woodworking Construction Chemicals Textile	Portugal Spain
ROBIN	To create bioeconomy governance models to accelerate the circular bioeconomy transition.	Not-sector specific	Spain Greece Germany Ireland Slovakia
BIORADAR	To provide a monitoring system of the environmental, social and circularity of industrial bio-based system	Textile Packaging Fertilizers	Not region-specific
SUSTRACK	To help policymakers to develop sustainable pathways to implement circular biobased systems.	Construction Textile Chemical Plastic Energy	Not region-specific

BIORECER, BIOTRANSFORM, ESCIB, LCA4BIO ROBIN, SUSTRACK, and BIORADAR, projects are directly related to developing initiatives for monitoring circularity indicators. Projects such as LCA4BIO and ESCIB have a strong methodological component with a robust background within the consortium, so potential future tools may be designed based on the methodologies under development. ESCIB consortium is working on circularity assessment criteria and indicators that reflect the value of biomass cascading and resource efficiency. They are providing a circular assessment instrument framework, where metrics are integrated with a holistic approach.

On the other hand, BIORECER and ROBIN allow interaction with project toolkits that are available for testing at the time of writing the present deliverable. BIORECER develops a tool where biomass generators and potential biomass users interact each other. They address a mapping of biomass at regional level and explores the feasibility of strengthening existing certification schemes and setting a precedent for the integration of sustainable practices along different value chains (source: https://biorecer.eu/). ROBIN aims to equips regions with practical, ready-to-use tools to develop strategies within bioeconomy and the tool provides the evaluation of the sustainability depending on each applicable indicator result for each sector (https://robin-project.eu/).

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In terms of metrics, BIOTRANSFORM bases the definition of indicators for a macro-level scale, using indicators suggested in literature (Geng et al., 2012[19]) and considering them as proxy of environmental and socioeconomic impacts.

For the BIORADAR project, indicators are being defined at the time of drafting this report. A preliminary list has been recently published (Table 2), considering the targeted sectors: textile, fertilization, and packaging.

Table 2 Preview of some circularity indicators of BIORADAR project[5]

Category	Description
General Circularity Indicators	Circular index (Enel, 2018): Measures product lifetime, use of recycled materials, and energy consumption from renewable sources.
	Biodegradable content (BIORADAR's brand new): Highlights the ability of materials to naturally degrade into non-polluting substances.
Fertilizer Circularity Indicators	Circularity Indicator of Nutrient (Cobo et al., 2018). Assesses nutrient recovery from waste streams.
	Nutrient Slow-Release Index (BIORADAR's brand new): Compares the ability of the fertilizer to slowly release nutrients to soil, reducing leakage and eutrophication risk.
Packaging Circularity Indicators	Recycling Effectiveness (Roithner & Rechberger, 2020): Evaluates how much material is recovered and reused in the final product.
	Virgin Material Consumption Index (BIORADAR's brand new): Tracks how much of the final product comes from virgin sources.
Textile Circularity Indicators	Resource pressure (Lama et al., 2022): Looks at recyclability and production efficiency, considering planetary boundaries.
	Fibre Treatment Circularity Index (BIORADAR's brand new): Measures the use of non-renewable chemicals in textile treatment.

The concepts underlying the definition of the BIORADAR indicators are the principles of the circular economy. However, basing the BioINSouth monitoring system fully on the BIORADAR indicators is not completely possible since they do not cover southern Europe regional challenges and BioINSouth is not a sector-specific project. Moreover, at the time of the present report, BIORADAR is still working with the industry on the validation process. They have received a qualitative validation of the KPI since the industry finds them reachable and interesting, however the validation with real-life case data is still in progress.

In summary, the clustering activities allowed to gain a better understanding of the approach taken by the most relevant ongoing UE projects, but it highlighted the lack of harmonisation in terms of circularity assessment and the lack of common indicators that could be fully adopted in BioINSouth. The reason for this may be due to the variety of bioproducts and bioprocesses that cannot be easily studied according to the same angles.

[5] https://www.bioradar.org/news/calling-bio-based-companies-participate-bioradars-circularity-assessment

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In view of the challenges of finding a common flag among the contacted projects, a specific questionnaire was developed to gather individual feedback from each consortium. With the objective of get knowledge about the experiences in defining methodologies and indicators for circularity assessment, the questionnaire contained 3 questions:

- Which approach do you recommend for the evaluation of circularity performance of bioeconomy systems?
- Which aspects should be included in studies of circularity of bioeconomy?
- What additional sustainability aspects should be included in a circularity assessment of bioeconomy systems?

The following charts show the responses retrieved from 7 projects (anonymous answers).

Figure 5 Approaches recommended to evaluate circularity of bioeconomy

Figure 6 Aspects that should complement circularity assessment of bioeconomy

From the feedback received, circularity assessments should focus on products rather than countries and resource use efficiency should be always assessed as part of the evaluation. Moreover, socio-economic dimensions and land use impacts can be a useful complement of this kind of studies.

The third question offered the possibility to provide non-guided feedback. Projects indicated the need to assess GHG impact, emphasizing the importance of evaluating the carbon footprint across the lifecycle of bio-based products. Responses also point to the significance of incorporating socio-economic dimensions, as well as considering ecosystem services and regenerative practices. Additionally, the one project recommended to include criticality that emphasizes the importance of evaluating the availability and sustainability of raw materials. Finally, ethical concerns around biomass use were raised, questioning

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whether economic value or societal needs should dictate its use, with an emphasis on prioritizing sustainable and socially beneficial applications.

5 Circularity monitoring in BioINSouth

BioINSouth project aims to design a circularity monitoring system for the southern European bioeconomy sector. Due to the diversity of strategies adopted to measure circularity, standardized measurements of circularity, can provide a more robust evidence for how well circular economy principles are applied to each strategy and associated products[11]. In this sense, the recent published ISO 59020:2024 for measuring and assessing circularity performance, provides a valuable framework that can be adopted to face the BioINSouth objectives and regional challenges, under a harmonised understanding of the circular economy. Although some limitations exist to fully covered the particularities of the bioeconomy, this standard serves as inspiration for the BioINSouth monitoring structure.

ISO 59020:2024 (EN) are based on the ISO 59004 and ISO 59010 that provide vocabulary, principles and a guidance on the transition of business models. ISO 59020 serves to guide users of organizations for measuring and assessing their circularity, regardless of the sector and size. It is an applicable framework for different scales: from regional to product level, which covers all the cases analysed in the reviewed ongoing EU projects. It recommends complementing with methods to assess other sustainability impacts that are caused by the actions to achieve the circular objectives. This multiple approach is in line with the BioINSouth structure, where not only environment, but also biodiversity, land use dimensions are covered.

Like LCA methodology (ISO 14040 and 14044), the first step is to define the boundaries, followed by the data collection to complete the assessment and reporting at the end of the process (Figure 7).

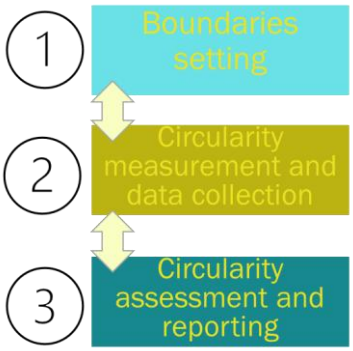

Figure 7 Stages for measuring and assessing circularity performance (source: ISO 59020:2024)

By applicating the scope of BioINSouth project, the following sections provide the guidelines for the application of a circularity monitoring systems, in line with the ISO recommendations and adopted to the HUBs context and regional characteristics.

5.1 Boundaries setting

Each regional HUB need to agree on the **system definition** to which the monitoring of circularity will be contextualized, which consider the areas where the Southern regional innovation ecosystem focuses. HUBs should define boundaries considering the limits of what is included and what is not included in the circularity monitoring, which will represent the **system in focus,** specifying the locations and the part of the value chain covered by the HUBs activities.

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Once the system is defined, HUB should define their regional circular goals that should reflect the efficiency of the circularity actions (reduce, reuse, recycle, valorisation…etc). Example of **circular goals** are: %increase of biomass recovered, %reduction of biomass losses.

Complementary, the ISO standard recommends the definition of data quality requirements, and specification of complementary methods to measure other aspects of sustainability. Moreover, it is of relevance to identify the interested parties. In line with the project HUB guidelines delivered in WP3, the interested parties would be all the actors identified in the network of each HUB. Also, in terms of transparency, the boundaries setting should include the decision about the dissemination: which results will be for external or internal communication.

Each regional HUB should identify the flows that can be internal or external to the system in focus. Those flows will be the basis for the quantification of indicators and can be clasifed as virgin inflows, outflows not recovered, resources recovered or circular resources in the wider economy. The decision about the temporary of indicators reporting is part of the boundaries setting and it should be decided directly at the time of the platform (toolkit) configuration.

Finally, HUBs should also work on the definition of the system perspective. In terms of BioINSouth project, HUBs will work at regional level by assessing the interactions within cities, districts or local areas. On the other hand, project HUBs that are focused on biorefineries operation should consider defining systems based on products, where HUB participants should have access to primary data from the value chain.

5.2 Circularity metrics (KPIs) and data collection

The circularity indicators allow the measurement of resources flow and the monitoring of the circular goals of the system previously defined as “system of focus”. In BioINSouth indicators are defined for the monitoring of resources flows (input and outputs) since the project focuses the actions on the bioeconomy sector with emphasis on biomass valorisation. Although, energy and water are also aspects of interest for the circularity, they are already covered as environmental aspects that directly contribute to the environmental footprint, which is addressed separately in the LCA.

For data collection, each HUB should gather information identifying the data sources. Data will be needed regarding inputs and outputs. Regarding input flows:

- Reused content
- Recycled content
- Renewable content
- Non-renewable content

Regarding output outflows, information will be gathered in terms of:

- Components and products that are reused
- Recycled materials derived from outflow
- Products and materials for renewable recirculation

Due to the large variety of HUBs and regions in the project, a set of generic indicators for the monitoring system are defined as a preliminary approach of the circularity indicators (KPIs) (Table 3).

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Table 3 Circularity indicators for the monitoring system

INDICATOR CATEGORY	KPI
Resource inflows	Average reused content of an inflow
	Average recycled content of an inflow
	Average renewable content of an inflow
Resources outflows	Per cent actual reused products and components derived from outflows
	Per cent actual recycled products and components derived from outflows
	Per cent actual recirculation of outflow in the biological cycle

Figure 8 identifies the flows that should be quantified by the HUBs participants. Both, primary and secondary data sources will be used and will represent the data input for the toolkit, where the calculation of the KPIs will be displayed as part of the circularity monitoring system.

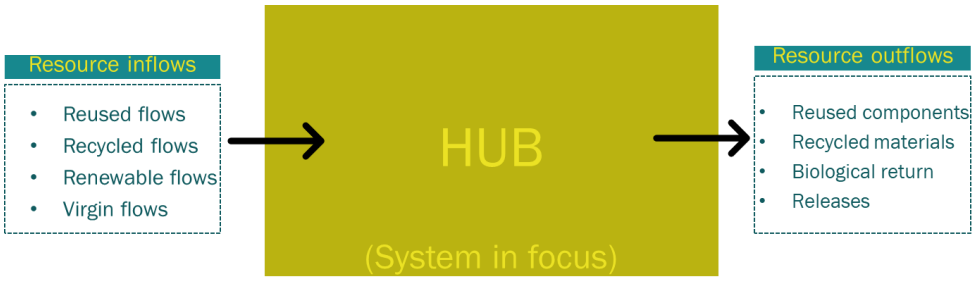

Figure 8 Flows to be quantified as basis for KPI calculations

Due to the large variety of systems in focus that can be defined for each regional HUB, flows should be identified individually for each case. Regarding HUBs focused on waste management activities or biorefinery operations, flows will be identified directly at production level (system in focus defined for products). For the case of HUBs more dedicated to innovation activities, flows should be identified in relation to the bioeconomy projects in which the HUBs implement circular strategies or promote innovations (system in focus defined at regional or local level).

5.3 Circularity monitoring and reporting

Once the KPIs are calculated, results from the measurement will allow the HUBs to interpret how well the system in focus is performing under the circular principles. The circular principles should have been the basis for setting the previously defined circularity goals. The interpretation of the circularity KPIs should be carried out together with the monitoring of the environmental footprint, biodiversity and land use impacts. A holistic assessment will be a fundamental aspect in developing regional activities which ensure the incorporation of ecological limits into the biological economy strategies and roadmaps.

The reporting of the circularity monitoring results will depend on the targeted audience defined for each regional HUB. Interested parties should find the information reported useful to progress on decision-making processes. To achieve a good interpretation and understanding of the KPIs, illustrative presentation of results may be of help, while transparency and limitation due to uncertainties in the data collection should be also explained.

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6 Validation and next steps

In the next steps of the project, in the context of WP3 and WP5, the described monitoring methodology will be validated and integrated into the BIoINSouth toolkit. To do so, a strong interaction with HUBs coordinators is foreseen to support them in the definition of the boundaries that will be basis for the data collection and calculation of KPIs. The monitoring system for each individual HUB will be adapted during the validation process, while the essential core of the methodology will be kept along the regions (as described in section 5.3). WP5 will oversee the data and feedback collection from the stakeholders that will allow the improvement of the monitoring system to be potentially adopted by the BioINSouth regional HUBs.

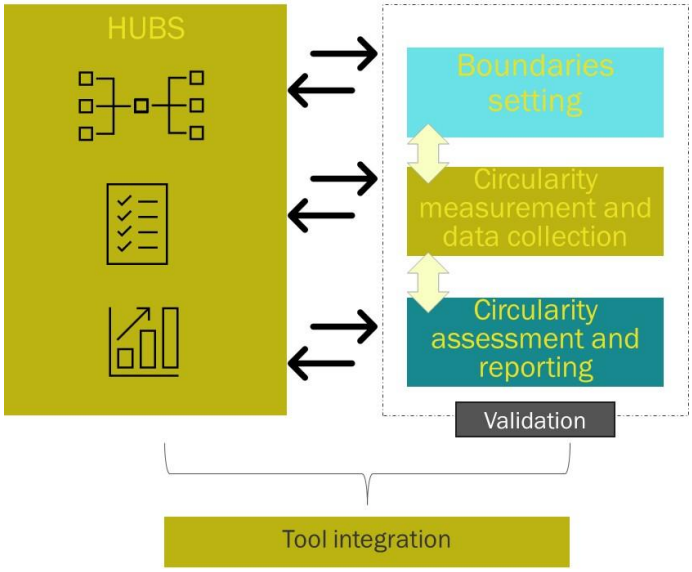

Figure 9 Validation and integration of the circularity monitoring system

As a first step towards the integration of a circularity calculation into the project toolkit, an excel-base tool has been shared with the toolkit developers (Figure 10).

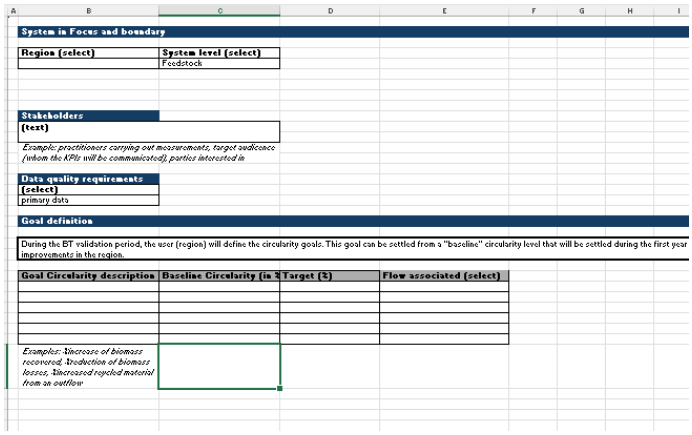

Figure 10 Screenshot of the 1st draft of the calculation module for circularity monitoring

Moreover, and prior to the official start of the validation process, the MARGs, and potential future members of the BioINSouth HUBs, were asked during the Kick off meetings in each region, to provide

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insights on the main areas of action which is essential information to identify KPIs and to anticipate data requirements. Under this goal, a questionnaire was developed to explore the areas of interest (education, legislation, ...), the scale of the actions planned, the biomass preferences and the target that would benefit most by the HUBs actions. BioINSouth HUB Coordinators gathered the feedback during the KOMs, and the following section graphically represents the feedback received region by region.

A sum of 75 people participated in the questionnaire along the regions. The following questions were the ones the MARGs, and potentially future members of the HUBs, answered to:

- What do you think will be the main area of action of the BioINSouth Hub in your region?
- At which level the BioINSouth HUB action will have the greatest impact?
- To which biomass (sectors) do you think the HUB's action will be more oriented?
- Which stakeholders will benefit most from the HUB's actions?

Table 4 shows the responses received region by region to facilitate the definition of circularity strategies, which should be customized for each HUB during the next project steps. As observed, the biomass exploitation will be a priority in Slovenia, Centro Region and Andalucia. For these cases, the system of focus will be mainly scoped for industry, forestry and agricultural biomasses, respectively. All the responses pointed out that the region will be the scale to which the monitoring system should be defined, which means that synergies of industries and bioeconomic activities should be considered, and aggregated data will be required for the KPIs quantification. Except for Peloponnese, where there is a clear preference towards academic activities, all the HUBs identified industry as the main beneficiary of the areas of focus.

Table 4. Graphical representation of the feedback received from the MARGs and future members of the HUBs.

BioINSouth Region	Main area	Level of impact	Most oriented biomass sector	Most benefitted stakeholders
Chart legend	Education/Engagement Legislation/Policy Biomass exploitation R&D projects	Regional Local Industry Market (products)	Agriculture Aquaculture Forestry Livestock Municipal waste Industry biowaste	Industry Citizens Local goverments Academic/research insitutions
Slovenia				
Centro Region				

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BioINSouth Region	Main area	Level of impact	Most oriented biomass sector	Most benefitted stakeholders
Chart legend	■ Education/Engagement ■ Legislation/Policy ■ Biomass exploitation ■ R&D projects	■ Regional ■ Local ■ Industry ■ Market (products)	■ Agriculture ■ Aquaculture ■ Forestry ■ Livestock ■ Municipal waste ■ Industry biowaste	■ Industry ■ Citizens ■ Local goverments ■ Academic/research insitutions
Andalusia[6]				
Cyprus				
Campania				
Peloponnese				
Asturias				
Nouvelle-Aquitaine				

[6] Andalusia MARG members marked more than one answer per question.

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7 Conclusions

Circular bioeconomy provides benefits in terms of the creation of new green jobs, the provision of additional income for farmers, foresters, or the increase of the carbon sink capacity. However, its development must be accompanied by solutions to provide sustainable and circular value chains according to the cascading principle, and the valorisation of bio-waste and by-products, while reducing pressure on the environment. In this sense, the evaluation of circularity provides useful information to manage and maximize the sustainability of the bioeconomy.

In terms of circularity indicators, different gaps were extensively studied in literature concluding that the lack of common guidelines for the identification and calculation of indicators, together with the challenges of different scales made it difficult to evaluating the circularity performance in bioeconomy.

Several aspects of metrics could be potentially improved[17], by incorporating tailored monitoring frameworks, by allowing to identify and visualize trade-offs and synergies between the Sustainable Development foals or by defining sustainability thresholds.

The indicators defined in this monitoring framework allow the assessment of circularity in the Southern regions through the evaluation of the BioINSouth HUBS in contributing to a more sustainable bioeconomy. By quantifying how well resources are used, reused and cascaded by the key actions planned in the HUBs, the framework provides a good basis for defining future strategies.

The diversity of regions and priorities of the HUBs may anticipate challenges in adopting common circularity targets or using the same data sources. To mitigate these challenges, the monitoring system proposes a broad framework that can be easily adapted with a case-by-case approach. Nevertheless, the validation process should prioritise the implementation of the framework in those regions where there is a clear focus on biomass exploitation, as the underlying concept of monitoring is based on the accountability of input and output resources flows.

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BioINSouth Info Box

The BioINSouth project aims to support decision-makers to incorporate considerations of ecological limits into their regional bioeconomy strategies and roadmaps relevant to circular bio-based activities. We aim to develop guidelines and digital tools, considering the safe and sustainable by design (SSbD) assessment framework, to support the adoption of innovative methodologies to assess environmental impacts in multiple industrial bio-based systems, increasing regional competitiveness and innovation capacity, and contributing to the EU fair & green transition.

Find out more:

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