Biological Resources Certifications Schemes

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Authors

Name	Organisation	Email
Maria Batsioula	CERTH	m.batsioula@certh.gr
Anthoula Karanasiou	CERTH	akaranasiou@certh.gr
Stamatia Skoutida	CERTH	st.skoutida@certh.gr
Sotiris I. Patsios	CERTH	patsios@certh.gr
George F. Banias	CERTH	g.banias@certh.gr

Type

☒	**R**	Document report
☐	**DEM**	Demonstrator, pilot, prototype
☐	**DEC**	Websites, patent fillings, videos, etc.
☐	**OTHER**	

Dissemination Level

☒	**PU**	Public, fully open, e.g., web
☐	**SEN**	Sensitive, limited under the conditions of the Grant Agreement
☐	**CI**	Classified, information as referred to in Commission Decision 1001/844/EC

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Lead beneficiary

CERTH (Maria Batsioula, Anthoula Karanasiou, Stamatia Skoutida, Sotiris Patsios, George F. Banias)

Contributing beneficiaries

CETAQUA (Lucía González Monjardin), ANFACO (Martín Rodríguez Álvarez), UNIVPM (Elisa Blumenthal), PROCESSUM (Anneli Sundman), USC (Sofía Estévez Rivadulla), CAN (Daniela Quaggia), UNITELMA (Annarita Colasante), MEO Carbon (Monica Pandey), NOVA (Asta Partanen, Anke Schwarzenberger), ICL (Elisa Nika), BRUNEL (Sebelan Danishvar), UNI (Cristina Dimaria), EGM (Romain Magnani)

Internal reviewer(s)

Name	Organization	Email
Lucía González Monjardin	CETAQUA	lucia-jimena.gonzalez@cetaqua.com
Martín Rodríguez Álvarez	ANFACO	mralvarez@anfaco.es
Daniela Quaggia	CAN	d.quaggia@activecitizenship.net
Isabel Burdallo	RISE	isabel.burdallo@ri.se
Lara Claret	SPRING	
Monica Pandey	MEO Carbon	pandey@meo-carbon.com

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Publishable executive summary

Deliverable 6.3 presents the Transferability and Replicability Plan of the BioReCer project, designed to ensure that the framework, tools, and methodologies developed within the project can be applied beyond the initial case studies. Building on core project outputs, including the Sustainability and Circularity Assessment Framework, the Innovation Ecosystem Living Lab, and the ICT tool, the plan defines a structured approach for replication, covering the assessment of local needs, stakeholder engagement, resource mapping, indicator selection, and integration of outcomes into certification schemes. At the European level, replication of BioReCer's results is most straightforward in sectors where sufficient data and information are available, such as the agricultural sector, while other sectors, such as fisheries, require greater adaptation to local conditions. Key findings highlight the importance of data harmonisation, stakeholder engagement, and flexible approaches to address regulatory and logistical challenges. At the international level, semi-structured interviews confirmed that BioReCer's tools and methodologies are considered valuable complements to existing certification schemes, particularly for enhancing traceability and credibility. Stakeholders emphasised the need for closer alignment with established standards, clearer communication of added value, and the integration of forward-looking circularity indicators. Overall, Deliverable 6.3 demonstrates that replication and transferability of the BioReCer's solutions are feasible and practical, provided that context-specific adaptationsare made, and the active involvement of relevant stakeholders is ensured. The plan offers concrete guidance for scaling-up BioReCer's approach, contributing to the development of sustainable, traceable, and circular bio-based value chains across Europe and globally.

1 Introduction

The transition to a bio-based economy is expected to deliver substantial environmental, economic and social benefits. However, bio-based production systems still come with significant environmental challenges, and there is a need for assessment methods that are adapted to the specific characteristics of these systems. BioReCer aims to ensure the environmental performance and traceability of the biological feedstock used by the bio-based industries (except for food, feed and bioenergy applications), deploying guidelines to strengthen the current certification schemes (Figure 1).

Figure 1: Schematic representation of the BioReCer project

Replicability and transferability are key element of the BioReCer concept, and this is reflected in its structure as it is built upon three main technological pillars: i) to develop a multidimensional assessment framework for an aggregated analysis on the biological feedstocks and their associated supply chains; ii) to create a BioReCer Innovation ecosystem living-lab with a multi-agent approach, testing the framework in 4 bio-based systems supply chain cases of study; and iii) to use all this knowledge to complement current certification schemes including new criteria for certifying biological resources' sustainability, origin, and traceability, and ensure applicability at EU and global scale. The main objectives of Work Package 6 (WP6) (and especially of Task 6.2 "Replication and transferability analysis") are the application of the BioReCer model in strategic sectors related to production and trade of biological resources, as well as in other biomass flows not only in Europe but across a broader global context.

1.1 Scope and objectives of the Deliverable

Replication as a word in its exact meaning refers to reproducing something, while transfer has to do with moving something from one place to another. Nonetheless, when it comes to replication and transfer of results, it should be understood as a wider concept. The need for replication and transfer of the project's methodology, outcomes and products to other contexts and geographical areas, regardless of different climate conditions, socioeconomic and cultural backgrounds, is crucial for moving forward the biological resources and the respective bio-based systems, in terms of sustainability. Thus, the different aspects and components of the solution and practices developed should be considered to support the needs of stakeholders. If an approach was proven successful in one regional value chain, it could be replicated in other cases on a national or international level, taking into consideration that the boundary conditions may be different from those tested in the four case studies of the BioReCer project.

In this sense, this document is a core part of BioReCer outcomes, as a critical choice to ensure that the project's outcomes are applicable not only to the designated case studies but in a broader European and global context. This involves supporting the uptake of BioReCer's solutions in other European regions and/or global areas and value chains, ensuring its applicability in diverse geographical and socio-economic conditions. The replication and transfer scope extends to a thorough identification of "elsewhere," meaning the careful determination of where, when, and why the BioReCer approach can be successfully transferred and replicated. Thus, the Transferability and Replicability Plan offers a strategy for sharing knowledge and experience acting as a guideline that does not concentrate on copying the full solution, but to the more likely scenario of employing parts of the solution by adopting different components either directly and/or by adjusting or repurposing them to fit into different contexts.

1.2 Structure of the report

This deliverable is connected to task 6.2 "Replication and transferability analysis" of WP6 – Demonstration of the developed methodologies on the 4 case studies and study of replicability /transferability. The deliverable consists of 7 chapters and their subchapters, presented as follows:

- **Chapter 1** introduces the deliverable, its purpose, and objectives. It explains how this deliverable connects with other tasks and work packages and provides an overview of the replication and transferability process.
- **Chapter 2** outlines the general approach to replicating/transferring the BioReCer concepts, also describing the replication approach's systematisation.
- **Chapter 3** elaborates on the various BioReCer outcomes and results that can be transferred and applied to different settings.

- **Chapter 4** presents the project methods and tools that facilitate the replication process.
- **Chapter 5** provides an overview of the stepwise approach, helping users visualise their roadmap towards BioReCer outcomes implementation.
- **Chapter 6** provides detailed replication examples at European and international level. The replication processes are tailored to each case study's unique conditions and challenges.
- **Chapter 7** offers final conclusions for implementing BioReCer's solutions across other European areas and international value chains.

1.3 Relation to other Tasks and Deliverables

Deliverable D6.3 outlines a comprehensive Transferability and Replicability Plan, building upon the tools and methodologies developed throughout the project. This deliverable is closely interconnected with all Work Packages (WPs) and Tasks, as it draws upon their outcomes to facilitate the sharing of knowledge and best practices. D6.3 serves as the basis for replicating or adapting either all or part of the BioReCer project's results in different contexts.

2 BioReCer transferability and replicability approach

The transferability and replicability approach within the BioReCer project is understood as the strategy to ensure the wider adoption of bio-based certified systems adding value to biological feedstocks and their associated supply chains. In this section, the overall transferability and replicability approach is outlined, including a clear set of activities for replicating BioReCer in other European and international regions and value chains.

Replicability refers to implementing a proven bio-based value chain concept / result (including assessment framework, indicators and certification scheme) in a different location under similar conditions, using the same or closely aligned components and methodologies. On the other hand, **transferability** refers to the ability of methodologies, techniques, or practices to be adapted and applied in different contexts, sectors, or value chains.

These two concepts address the reuse of project outcomes across contexts with different boundaries and conditions. In other words, if a pilot/use case/project proves that it works and is successful, it can be expanded to other regions, but different conditions must be carefully taken into account since they can significantly influence the outcomes. To this end, BioReCer solutions can be replicated directly or transferred through adaptation of the original concept to a different setting, generating a comparable outcome in another location. However, the technical characteristics are the components that make the solution finally work for intended use. Thus, the technological aspects of a platform or a database can be reused as is or modified through a co-creation process to meet the specific needs of the users. As such, assessing the replicability and transferability entails determining which components of BioReCer could potentially be transferred directly and which must be modified. Moreover, the approach developed in the frame of the project along with the lessons learnt in each case establishes an enabling environment for the solution's implementation.

Replicability and transferability should not only focus on the full solution scenario but also investigate its different components and examine how some of these can be used for different cases. Therefore, the BioReCer case studies have been the key in the definition process of the replicability and transferability approach to be followed. This is because the plan aims to replicate and transfer the adopted solutions in other regions and value chains building on the use cases' lessons and extending their insights. The strategy's ultimate goal is divided into two parts: (i) the short-term goal of implementing the

BioReCer results in other European regions of the project countries, and (ii) the long-term goal of expanding its tools and databases to include data from other countries around the world so that it can be transferred into other (international) value chains. The steps for replicability/transferability involve precise identification of what is being replicated and its related components. In the case of BioReCer, replicability focuses on the project's key exploitable results and their implementation in similar contexts.

As previously mentioned, to replicate or transfer results, it is important to understand how different aspects can be replicated or used for multiple cases. Each solution may have specific technical characteristics, an alternative approach, or present a special use case scenario. Nevertheless, it is critical for the transferability and replicability approach to be simple and streamlined while retaining the necessary components. In this context, an interactive process of gradual build-up of Transferability and Replicability planning has been developed. To fulfil the objectives of WP6 and address the main challenges to replication, the BioReCer transferability and replicability approach consists of 5 building blocks that reinforce one another (Figure 2). They can be regarded as complementary and progressive steps leading to the replication and transfer of project solutions, but they do not have to be interpreted as strictly consecutive blocks.

Figure 2: BioReCer transferability and replicability approach

When considering a result to be replicated and/or transferred, the steps foreseen for this process are the following:

- **Get started: identify the rationale and determine the vision**
  The first step towards replication/transfer of a new solution / BioReCer outcome is to develop a rationale that outlines the issues faced within an area or value chain, as well as the specific demands of the relevant stakeholders. Taking into account that the challenges and solutions given for replication are tailored to the users' individual needs, the likelihood of creating an enabling environment for successful replication is significantly increased.
- **Specify: selecting a replicable solution**
  Once the scope has been specified, the next step is to look at the potential solutions. A collection of replicable results tested and validated as part of the BioReCer project is offered to help determine which key exploitable results can be adapted for replication/transfer in a different context to create a new outcome. When a potential solution has been identified, a series of questions need to be considered to determine which technical components can be replicated/ transferred, as well as to assess the feasibility of their practical implementation.
- **Adjust: setting up the application range for BioReCer**
  To replicate/transfer a solution, a number of additional factors must be considered beforehand to ensure that implementation is feasible. These are the contextual variables in the solution that creates an enabling environment. To this end, this step corresponds to the evaluation of topics such as the profile of interested stakeholders and partners, as well as an assessment of local boundaries, conditions, constraints, assets and limitations to define users and use cases as a baseline for BioReCer applications.
- **Prepare: linking to solution**
  The main question to be answered is "What were the activities necessary to put the solution into place". Thus, the next phase encompasses the regular exchange of information on the state of the art of the products' development and implementation of solutions which forms the basis for learning and building trust. To facilitate replication/transfer processes, the project's knowledge will be captured in several **replication tools**, including webinars and capacity-building workshops, as well as a platform, by which replicators can build a specific knowledge and delve into the technical details of each outcome. Besides knowledge sharing, training and capacity building can also be an important step

of the replication/transfer process, since the replicators are equipped with techniques and methodologies they will use.

- **Moving forward: preparing for replication/transfer**
  The final step builds on the previous phases to advance towards the effective application of the solution in other regions and/or value chains. Nevertheless, implementation requires careful planning and ensuring that all contextual factors and adaptations are in place. To this end, a strategy for introducing the solution to a new context and facilitating its adaptation should be carried out. Based on the preparation of the previous phases, a roadmap will be prepared setting up the steps towards replication/transfer of the selected outcomes.

In any replication or transfer scenario, context-specific adaptations are required to ensure alignment with local regulatory frameworks, feedstock characteristics, infrastructure conditions, and stakeholder requirements. No situation fits all. Therefore, the changes that may be necessary to replicate/transfer a solution need to be examined. In any case, current practices will be considered, and the following processes will change by employing innovation. After all, the goal of a replicable solution is to inspire and contribute to the improvement of products, and processes through innovation.

3 Overview of BioReCer results

In the following section, a collection of replicable results, tested and validated in the context of the BioReCer project, are presented in an easy-to-follow manner.

3.1 BioReCer Sustainability and Circularity Assessment Framework for bio-based products

The **BioReCer Sustainability and Circularity Assessment Framework** offers a comprehensive theoretical foundation for evaluating the sustainability and circularity of biological feedstocks through a structured set of principles, criteria, and requirements based on three fundamental pillars - environmental, economic, and social.

It follows a hierarchical pyramidal structure, where principles, criteria, and requirements are interconnected (Figure 3). This approach enables the identification of overlapping requirements that align with multiple principles, ensuring a holistic evaluation of bio-based products. The BioReCer Sustainability and Circularity Assessment Framework consists of 52 requirements, encompassing both sustainability and circularity principles and criteria, which are classified into two categories:

- **Basic requirements** (29 total), which are **mandatory** and represent essential conditions for certification.
- **Advanced requirements** (23 total), which are **non-mandatory**, allowing organizations to enhance their practices beyond the minimum threshold without being excluded from certification.

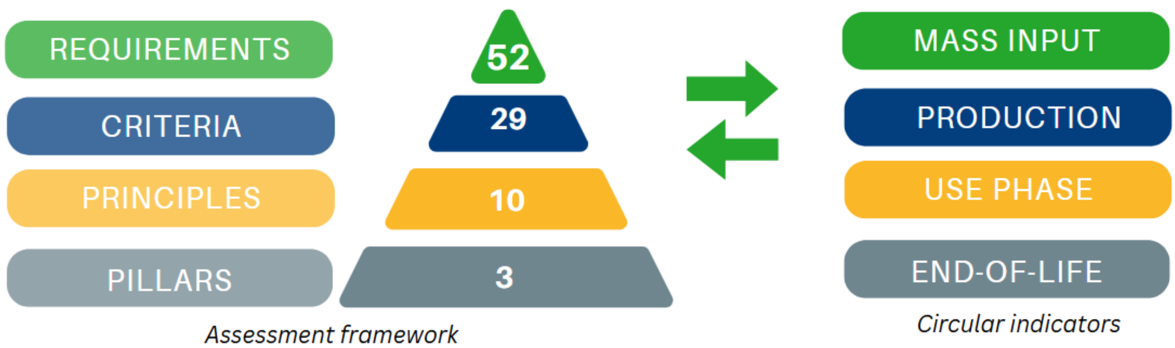

Figure 3: BioReCer Sustainability and Circularity Assessment Framework for bio-based products

By combining qualitative requirements with quantitative indicators, the BioReCer Sustainability and Circularity Assessment Framework provides a structured and adaptable approach for assessing the sustainability and circularity of bio-based products, supporting organizations in improving their environmental performance while ensuring alignment with circular economy (CE) principles.

3.2 BioResources Innovation Ecosystem Living Lab (BRIE-LL)

The **BRIE-LL** is a living lab initiative built around a dynamic community of practitioners, connected through a "phygital" approach, integrating both physical and digital interactions. It fosters collaboration and engagement among stakeholders and key actors involved in the project.

The BRIE-LL is structured around two complementary levels of interaction: a physical level, facilitated by the Bioresources Stakeholders Platform (BRSP), and a digital level, supported by the BioReCer ICT tool (BIT). Together, these tools mark important milestones in advancing collaborative frameworks within multi-stakeholder, bio-based initiatives.

The BRSP is designed to foster in-person engagement through participatory formats such as workshops, networking events, and training activities. It brings together a broad spectrum of stakeholders, ranging from certification bodies and biomass producers to bio-based industries and consumer organisations. Meanwhile, the BIT provides a digital space that complements BRSP activities, enabling virtual collaboration and supporting the methodological testing and validation of project's outputs. It also incorporates advanced technological components to further enrich stakeholder interaction and decision-making. Since both tools play a foundational role in enabling the co-creation and dissemination of BioReCer outcomes, a more detailed analysis of the BRSP and BIT will be presented in a later section.

Overall, the dual structure of the BRIE-LL creates a robust and dynamic framework for engagement. It ensures broad stakeholder participation across both physical and digital spaces, reinforcing the project's vision for a sustainable, inclusive, and data-driven bioeconomy.

3.3 BioReCer ICT tool (BIT)

The **BIT** is a comprehensive digital tool developed to enhance decision-making in the certification and validation of bio-based products. It is designed to address key challenges in sustainability assessment, traceability, and regulatory compliance within the bioeconomy.

One of its first core functionalities is the "**BitAdvisor**", the Decision Support System (DSS) which allows a user affiliated to a company to self-evaluate through the 52 Basic and Advanced requirements of the BioReCer Sustainability and Circularity Assessment Framework (Section 3.1). By answering a series of questions, the module generates, as output, some key indicators:

- **Score by pillars,** which evaluates performance in three critical areas: environmental, social, and economic.
- **Overall compliance**, which provides a holistic view of an industry's adherence to standards and best practices.
- **Score by sector**, which uses the NACE code system to compare the company performance against industry averages, offering a clear perspective on where they stand relative to competitors.
- **Recommendations** on how to increase the scoring of bio-industries, according to the responses obtained from the questionnaire.

The steps followed while using the BitAdvisor are shown in Figure 4.

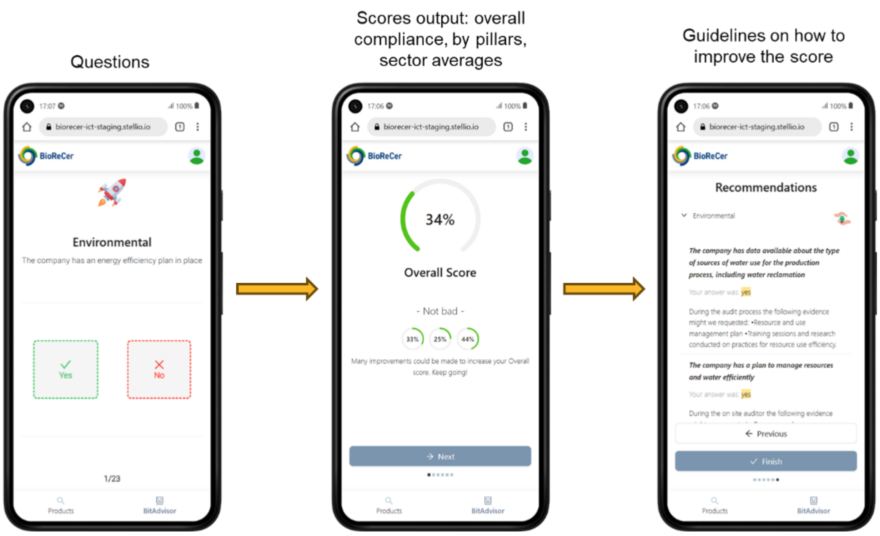

Figure 4: Illustration of the BitAdvisor usage sequence

Leveraging the EU's NGSI-LD Context Information standard, the tool provides access to contextual data in time and space. This structured information facilitates the application of Life Cycle Assessment (LCA) methodologies, although the tool itself does not perform LCA calculations. The interface allows users to follow the chain by inspecting related inputs or outputs. At any point, users can view environmental-related information for each process, such as energy, water, or chemical requirements, and carbon footprint, as illustrated in Figure 5.

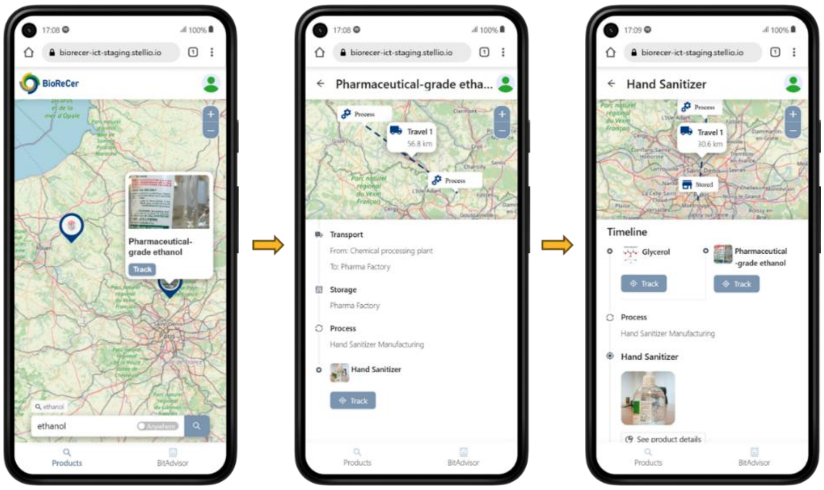

Figure 5: Illustration of the Life cycle assessment feature usage sequence

At each step of the supply chain, the user can assess the carbon footprint associated with the transport route in the dedicated product page. When available, additional details, such as circularity indicators, mass, and the share of the product used as an input, are also provided (Figure 6).

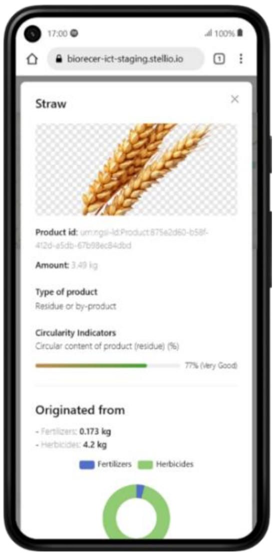

Figure 6: The product details page shows circular indicators, mass and share of product used as input, carbon footprint.

In the short-term future, more information could be added such as the certification schemes related to a product, and the total calculation at a given point in time in the supply chain, of the energy consumption, water and chemical requirements, carbon footprint, etc.

3.4 BioReCer practical guidance document for integration of the BioReCer Sustainability and Circularity Assessment Framework into existing certification schemes

The **BioReCer practical guidance document** focuses on clarifying the interpretation of BioReCer's criteria and helping certification schemes better understand how to assess compliance with its sustainability and circularity requirements.

The BioReCer project aims to complement and strengthen the existing certification schemes by providing comprehensive criteria and requirements to evaluate environmental and social performance, as well as traceability of the biological feedstocks used by bio-based industries. Although it provides a strong theoretical ground to assess the sustainability and circularity of biological feedstocks, it is not designed to function as a standalone certification scheme but is intended to be used alongside the main certification scheme. To support this, a practical guidance document has been developed to clarify the interpretation of BioReCer's criteria and to help certification schemes better understand how to assess compliance with its sustainability and circularity requirements.

To facilitate the assessment of the feasibility to incorporate the requirements of the BioReCer Sustainability and Circularity Assessment Framework into existing certification schemes, the practical guidance document provides guidelines on the integration process. The document provides a detailed description of how to assess the compatibility between the requirements of certification schemes and the BioReCer Sustainability and Circularity Assessment Framework, approaches for integration into the certification scheme and how to align the certification process. Moreover, verification guidance was developed by conducting a comparative analysis (benchmark) of existing bio-based certification schemes across four sectors (fishery, wastewater, forestry, and agriculture), against the BioReCer Sustainability and Circularity Assessment Framework. The analysis focused on environmental and social sustainability, traceability, governance, and circularity aspects. The verification guidance thus includes a clear description of the requirements of the BioReCer Sustainability and Circularity Assessment Framework, circularity indicators linked to each requirement and instructions on how to assess these requirements. Besides that, the audit checklist document outlines clear means of verification for compliance with the BioReCer Sustainability and Circularity Assessment Framework. It also offers guidance on how certification bodies should conduct their assessments and verification processes, ensuring consistency, transparency, and reliability throughout the process.

4 Portfolio of enablers for replicability and transferability

The BioReCer project has developed a series of “tools” to support the adoption of bio-based residual resources as raw materials in bio-based value chains, such as monitoring (using the BIT) and their certification (via an updated certification scheme). **The main available resources developed by the BioReCer project, as briefly introduced below, are freely available to any user through the project's website https://biorecer.eu/**.

4.1 BioResources Stakeholders Platform (BRSP)

The **BRSP** is designed to engage a diverse range of stakeholders, each playing a crucial role in developing optimised models, for assessing the environmental sustainability and traceability of biological resources.

The primary goal of the BRSP is to create an interactive community that collaborates with the BioReCer consortium, giving input, maximizing outreach, and amplifying its results. To this end, relevant stakeholder groups are identified and targeted engagement activities are launched to ensure broad participation across Europe. Once a substantial number of members join the BRSP, they are actively engaged in various activities, including:

- **Focus Groups** (FGs) to gather stakeholders’ perspectives on the project’s overall goals and potential barriers.
- **Analytical Hierarchy Process** (AHP) analysis to collect quantitative feedback and identify sustainability criteria relevant to different stakeholders.
- **Annual Multi-Stakeholder Meetings** to provide updates, consult participants on key project milestones, and integrate their insights.
- Invitation to **webinars and external conferences**, including those organised in collaboration with or by related projects.
- **Interviews** as part of a dedicated communication campaign to increase visibility and share stakeholder perspectives.
- **Subscription opportunities** for the project newsletter and engagement through the BioReCer LinkedIn group and the LinkedIn group jointly established with related bio-based certification projects.

- **Training sessions, brainstorming workshops, and other interactive activities** conducted both online and in-person at various project meetings.
- Involvement in **socio-economic initiatives**, such as field experiments and Delphi Surveys, ensuring that stakeholder expertise contributed to real-world applications.

4.2 Interaction protocols

A **Stakeholder Involvement Plan (SIP)** has been developed to serve as a structured tool to coordinate and optimise the different stakeholder engagement activities (focus groups, interactive sessions, surveys, public events, field experiment, study visits, training capsules, etc.).

Updated every six months, the SIP includes an Excel tracker shared with project partners to map out stakeholder involvement across WPs, ensuring efficient planning and avoiding duplication. The plan integrates a multilevel approach, balancing focused expert input with broader stakeholder involvement through various activities. This dynamic strategy enhances collaboration, maximises impact, and ensures alignment with project objectives. The SIP remains flexible and adaptive, evolving alongside the project to meet emerging needs.

4.3 Training capsules and Brainstorming sessions

Different **webinars, training sessions and brainstorming discussions** can be conducted to enhance stakeholders' understanding of the project advancement, the Sustainability and Circularity Assessment Framework, the new indicators of environmental sustainability, the ICT tool, etc.

These sessions can be delivered online or in person and are, most of the time, recorded and accessible to all stakeholders through a dedicated subpage of the project website. During these events stakeholders have the opportunity to participate in an interactive **training** and **trial** of the innovative ICT tool, be informed about sustainability indicators, the Sustainability and Circularity Assessment Framework, and tracking and traceability indicators, as well as be actively engaged in a site visit. Moreover, through semi-structured surveys (S2) the participants can provide additional feedback on the usability and development of the ICT tool.

4.4 MFA approach & I/O tables

4.4.1 Material Flow Analysis

Material Flow Analysis (MFA) represents a mass balance approach which allows a quantitative estimate of the stocks and flows of input, processing and output of materials/ substances/ products along a whole value chain within a well-defined system in space and time, i.e. industries, sectors or ecosystems (Brunner & Rechberger, 2016). To this end, MFA may act as a starting point for implementing an LCA assessment since it enhances the mapping of material and energy inputs and thus facilitates estimating of carbon footprint and other environmental impacts. It also facilitates the estimation of the circularity indicators developed in the context of the project.

In particular, MFA enhances the understanding of the material basis of the economy and the associated economic supply and demand issues. Furthermore, it facilitates the identification of inefficient use of natural resources, energy and materials in process or value chains or the economy in general, that would go undetected in conventional monitoring systems (OECD, 2008). In general, MFA supports the user to:

1. Understand and outline a system of material flows and stocks qualitatively, by utilizing precise and uniform terms with the selected system boundaries.
2. Monitor the material system over time, with a focus on past developments or to anticipate future trends by taking into account assumptions about progress such as new technologies or changing factors like consumer behaviour.
3. Simplify intricate systems while securing a basis for rational decision-making.
4. Implement the mass-balance principle, utilise quantitative terms and point out any sensitivities and uncertainties of the systems investigated.
5. Generate results about the flows and stocks in a reproducible, comprehensible, and transparent way.
6. Interpret the results, with emphasis on the management of resources, environment and waste, thus serving as a basis for assessment tools supporting the management of resources and wastes, and in parallel contributing to the timely prediction of problems such as future environmental burdens and resources depletion.

4.4.2 Input - Output tables

The **input-output tables** (I/O Tables) provide a tool for summarising in a compact and uniform way the quantitative information that describes each defined value chain.

More specifically, all the inflows (including the main feedstocks, additional raw materials, resources and utilities) and outflows (referring to the material streams, waste, losses and emissions) are provided. The I/O tables are accompanied by a concise flow diagram depicting the stages and flows of the value chain (Figure 7).

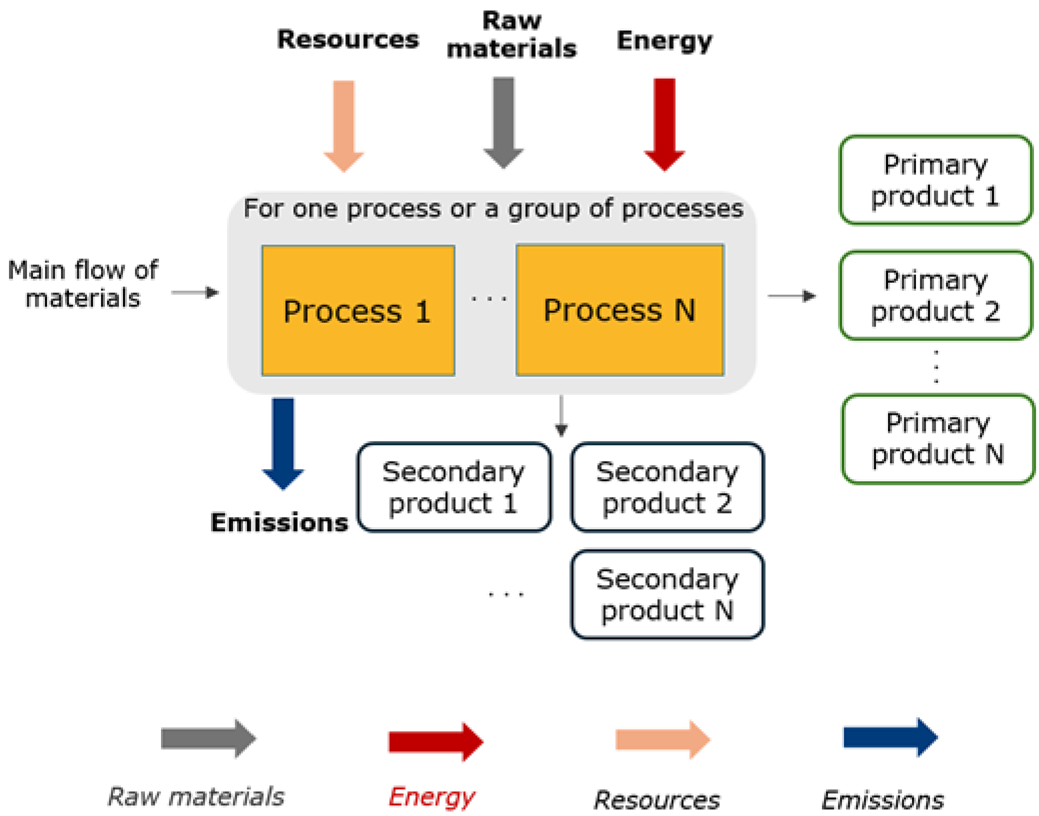

Figure 7: Schematic representation of the modules of the value chains that correspond to the I/O tables

Therefore, the data of the extended tables can be utilised as conversion coefficients for the estimation of (i) material conversion yields throughout the main stages of the value chain as well as important sub-processes, (ii) all the necessary inputs in terms of materials and energy that are required for the appropriate operation of each stage, (iii) flows of the main materials assessed covering the losses and alternative uses (where applicable), (iv) the creation of co-products, by-products, waste streams and emissions for each stage.

4.5 T&T Framework for circular value chain

Track and Traceability (T&T) framework enables a transition towards a circular bioeconomy by enhancing transparency, trustworthiness, and sustainability of bio-based value chains.

The T&T framework provides full, real-time tracking and tracing of bio-based materials from initial sourcing to end-use or recycling, offering in-depth transparency across supply chain activities. At the centre of the T&T paradigm is the intersection of emerging digital technologies, such as IoT-enabled sensors, blockchain, and cloud-based data analytics. Moreover, its architecture enables the integration of circularity indicators developed in a systemic way, thus allowing stakeholders to proactively look for areas of improvement and implement targeted strategies for enhancing circularity. Besides that, the T&T framework is flexible and adaptable to a variety of sectors offering broad scope applicability and robust operational backing in various bio-based environments.

Overall, the T&T framework fosters circular economy philosophies through transparency, reliability, and sustainability. By providing stakeholders with correct, timely, and actionable information, the T&T framework not only serves to ensure conformity with regulatory obligations but also facilitates active uptake of sustainable operations. The result is a pioneering, integrative digital solution that empowers stakeholders to achieve improved resource efficiency, reduced environmental impacts, and improved market competitiveness in a circular bioeconomy.

4.6 Biological Feedstock Label reporting on reliability, conformity, performance, and promotion

The **Biological Feedstock Label** is an advanced digital labelling system designed to communicate reliability, conformity, performance, and promotional attributes of bio-based materials across diverse supply chains. Meticulously crafted with the specific aim of offering enhanced transparency and traceability, this label strictly captures relevant data points from the origin of feedstocks all along their entire life cycle, so stakeholders are always able to access accurate, verifiable information.

Biological Feedstock Label significantly supports traceability, reliability, and sustainability objectives. It is an integrated system for promoting responsible and transparent handling of bio-based feedstocks, fostering trust and engagement between producers, regulators, and consumers. In particular, it integrates blockchain technology to ensure data immutability, transparency, and security, while automated validation routines continuously verify data accuracy and regulatory compliance. The system displays whether the industry holds certifications from recognised schemes such as ISCC PLUS, or FSC, along with details on their validity, without replacing the usual audit or reporting requirements. This harmonised approach enables producers, regulators, and consumers to easily access consistent, verifiable sustainability data and adapt to evolving market and policy requirements. The label also incorporates performance indicators, including real-time circularity, efficiency, and sustainability metrics, that generate actionable intelligence for operational improvement and sustainability reporting. Public access to this data fosters market transparency and consumer trust, ensuring that sustainability claims are both quantifiable and credible. Overall, the Biological Feedstock Label supports responsible bio-based production, strengthens stakeholder collaboration, and positions sustainable products more competitively in increasingly environmentally conscious markets.

4.7 Electronic Identification Passport (EIP)

The **EIP** in the BioReCer system is a central digital component, with complete documentation of biological feedstocks over their life cycle.

The Electronic Information Passport (EIP) establishes a unique digital identity for each batch of bio-based products, integrating key data such as origin, processing history, environmental performance, and compliance information to ensure transparency, accountability, and trust across the supply chain. Fully integrated with the BIT, it enables automated data capture and validation through IoT sensors or structured manual input, minimizing errors and enhancing data reliability. Leveraging blockchain technology, the EIP ensures tamper-proof, secure, and transparent records. Its scalable and modular infrastructure supports diverse bio-based sectors and adapts to varying regulatory and certification requirements. By consolidating lifecycle and certification data into a single electronic record, the EIP streamlines auditing and compliance verification, reducing administrative burdens and enhancing consumer confidence. All in all, it serves as a robust, future-ready digital tool that helps stakeholders continuously demonstrate sustainability compliance and strengthen long-term environmental stewardship.

4.8 Standardization toolkit

The **Standardization toolkit** offers an open online research tool to support the bio-based stakeholders in finding the right sustainability standard among the numerous European and International standards.

The toolkit is made by 2 dashboards: the first one, reorganizing 149 standards and the second one, 17 certification schemes.

4.8.1 The Standards Dashboard

This first interactive panel is a dataset of 149 national (Italian), European and international standards (UNI, EN and ISO respectively) relevant to the bio-based sector. Each standard includes details on its scope (e.g., biodegradable plastics, bioeconomy, environmental management), keywords (e.g., biodegradability, recycling, traceability), and is overseen by the technical committees from CEN, ISO, and UNI (e.g., CEN/TC 249 – Plastics, UNI/CT 600/SC 01 – Physical-chemical tests).

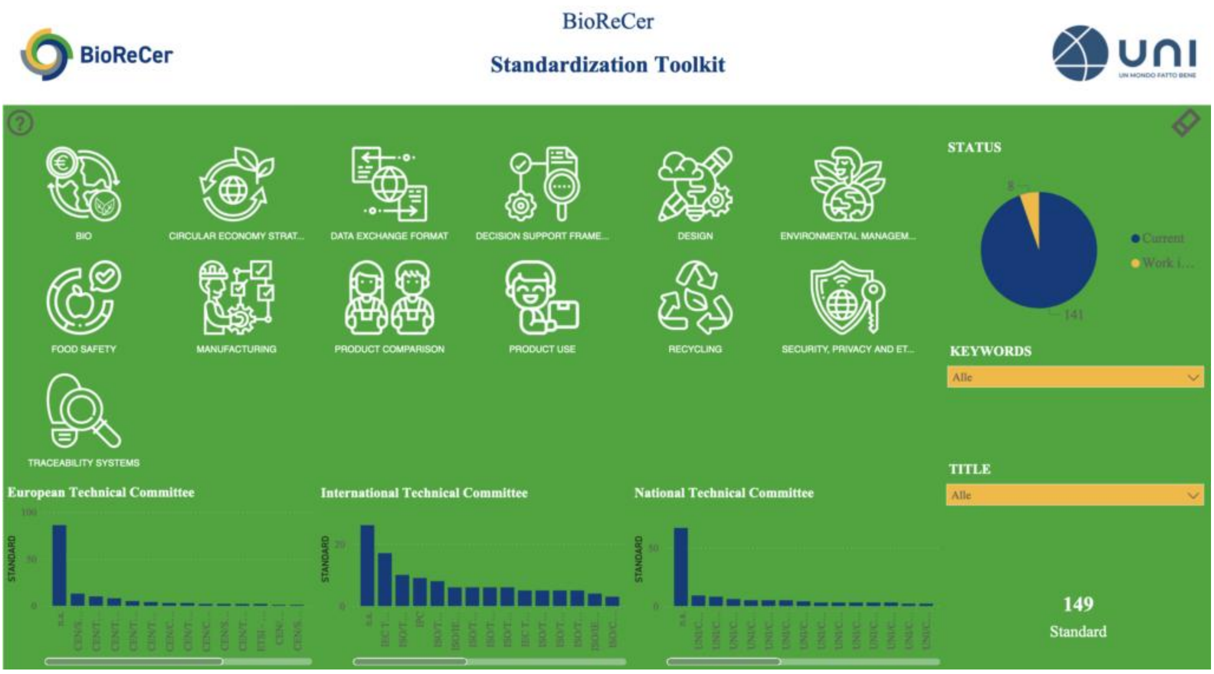

Figure 8: The Standards Dashboard of the standardization toolkit

4.8.2 The Certification Schemes Dashboard

The second panel provides detailed information about 17 certification schemes, including key schemes, such as ISCC, RSB, FSC, relevant to the bio-based sector. For each certification scheme, the user can find details on documents, scope (e.g., environmental management, biomass, agriculture), keywords, and status (either "current" or "in progress"). This dashboard offers a structured overview of certifications related to sustainability and traceability, helping professionals navigate and implement the most relevant schemes for their projects.

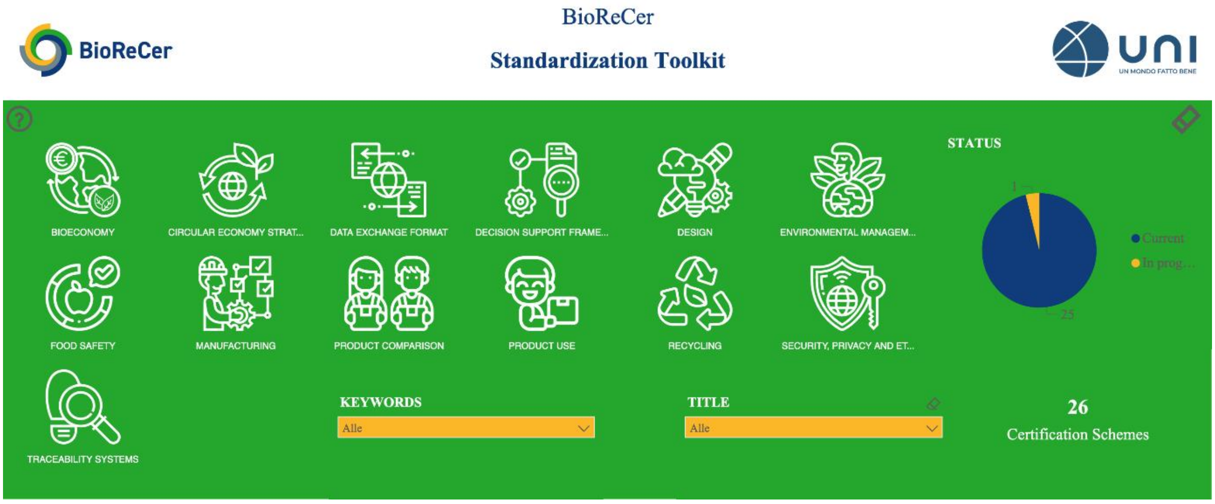

Figure 9: The Certification Schemes Dashboard of the standardization toolkit

The Standardization Toolkit is an invaluable resource for anyone interested in the bio-based sector and is freely accessible from the BioReCer website. By adhering to the highest standards and considering relevant certification schemes, stakeholders can adopt the best practices and contribute to successful outcomes in bio-based projects.

4.9 Strategic standardization roadmap

The **Standardization Roadmap** is a strategic document providing guidance to the Technical Committees of CEN (European Committee for Standardization) for new standardization efforts, supporting the market uptake of innovation in the bio-based sector, and facilitating the link between research and standardization.

The aim is to provide input for the standardization system through the conception of future, new standards and/or contributions to existing standards, specifically designed to support the bio-based stakeholders. These insights for standardization contributions offer inputs to the existing framework and represent a proactive step towards addressing existing gaps and anticipating the sector's needs, thereby steering the progression of the bio-based industry.

5 A stepwise journey

To fulfil the objectives of WP6, an interactive process of gradual build-up of Transferability and Replicability planning has been developed. To ensure the successful adaptation and application of BioReCer's solutions across different regions, and systemization of this approach, the transferability and replicability roadmap development process involves several key steps (Figure 10). These steps are designed to be comprehensive, flexible, and tailored to the specific needs and conditions of each location.

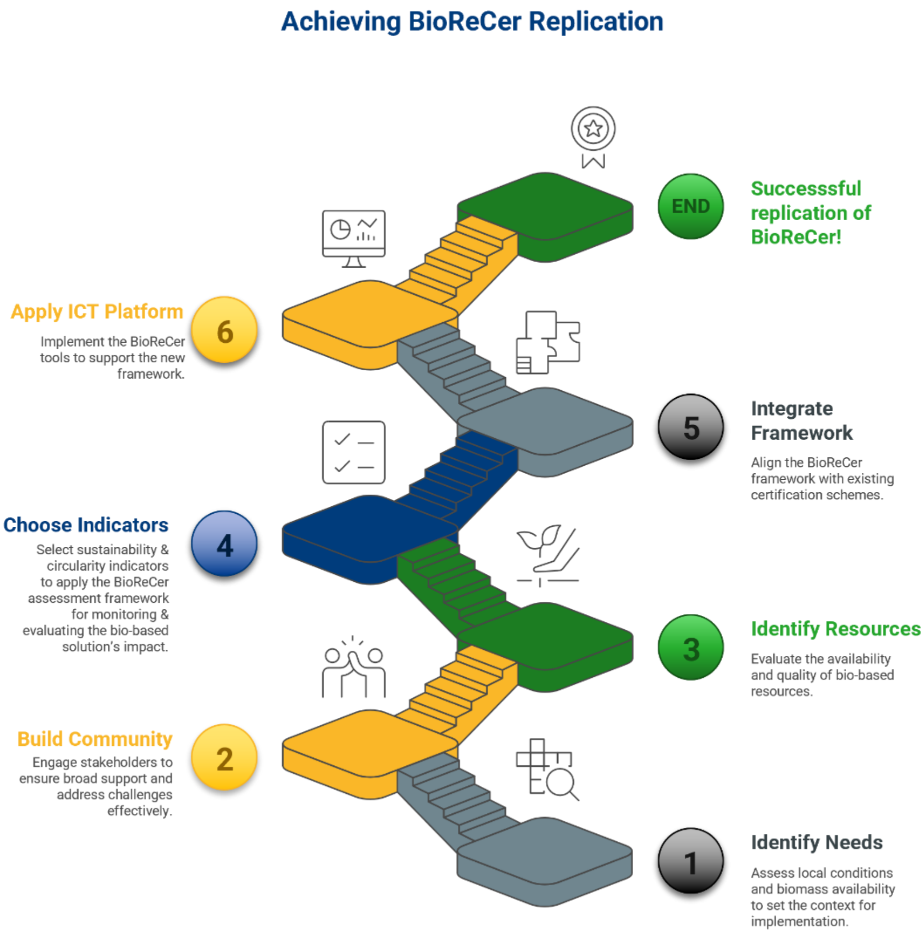

Figure 10: The BioReCer transferability and replicability roadmap development process

A detailed process is presented in Figure 10, while a short description of each step is provided in the following sub-sections.

5.1 Step 1: Identify your needs

The BioReCer transferability and replicability approach begins with the performance of a pre-replication assessment. This is a preliminary analysis, which includes an in-depth investigation of local circumstances, biomass availability and demands, as well as existing infrastructure creating a baseline for the existing bio-based value chains in the region. This step is essential for setting the foundations in which the BioReCer concepts and results will be implemented, guaranteeing that suggested solutions are tailored to the unique issues faced by each site.

5.2 Step 2: Build your action community

BioReCer is closely linked to local value chains and stakeholder groups. Thus, the early formulation of a strong and active group plays a significant role in the successful replication/transfer of the BioReCer outcomes to address rising challenges promptly, to fill-in gaps concerning local data, as well as to ensure broad support. Strong and constant stakeholder engagement is also to identify critical actors addressing legislative, operational challenges effectively, thus enabling high levels of interest and collaboration, facilitating a more seamless implementation and supporting the replication process.

5.2.1 Stakeholder mapping

As a critical first step, mapping the stakeholders helps ensure that key actors across the bio-based value chain are actively engaged from the outset. This process not only supports inclusive participation but also lays the groundwork for effective local governance within bio-product value chains. A well-balanced representation of stakeholders - including those involved in feedstock supply, processing, and end-use, is essential for a successful transition to a bio-based production system. Each phase of the project, from sourcing raw materials to delivering bio-based products, requires specific expertise and contributions. Figure 11 highlights the representative stakeholder groups typically involved throughout the development of a bio-based value chain.

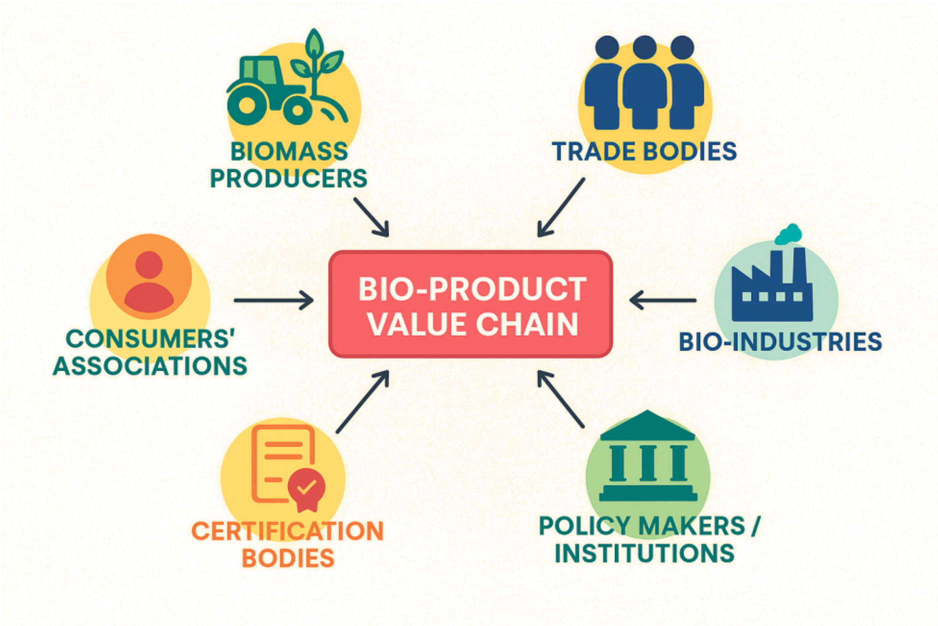

Figure 11: Stakeholder groups involved in a bio-product value chain.

In general, the anticipated work necessary for stakeholder mapping includes:

- **Identifying relevant stakeholders**: conduct a brainstorming session to identify all relevant individuals, groups, and organizations connected to or impacted by the project and generate a comprehensive list of stakeholders.
- **Assessing stakeholder roles and levels of engagement:** evaluate how actively each stakeholder should be involved, ranging from passive interest to active participation.
- **Analysing stakeholder interests and perspectives:** understand and document what each stakeholder values, expects, or seeks to achieve in relation to the project.
- **Mapping stakeholders to further determine which stakeholders are most essential to engage with:** draw a stakeholder map to see where stakeholders stand when evaluated with the same key criteria and compared to each other, thus visualizing the often-complex interplay of issues and relationships created.
- **Develop a targeted stakeholder engagement strategy:** create a plan for engaging stakeholders, tailored to their roles, needs, and profiles, ensuring meaningful and effective participation throughout the project lifecycle.

5.2.2 Engagement actions

Engaging stakeholders from the earliest stages - particularly in discussions around core assumptions, shared values, and setting project priorities - is strongly encouraged. This inclusive approach helps establish a trustworthy structure and contributes to the application of solutions that are both socially acceptable and aligned with community needs. The meetings, which are essential for effective collaboration, should be well-planned and not spontaneous to ensure productivity. Additionally, involving individuals or organizations with prior experience in the local context can help foresee and navigate potential social challenges in mobilizing community participation.

5.2.3 Mobilisation and outreach to wider community

To ensure strong stakeholder engagement, it is crucial to create opportunities for continuous interaction and knowledge exchange. This can be achieved through different activities such as:

- Organization of **annual interactive sessions** where stakeholders can follow the progress, contribute their insights, and see how their feedback is incorporated into the replicability/transferability process. These sessions should be open to a broader audience, leveraging partner networks, social media, and collaborations with related initiatives. Additionally, framing these events as training opportunities can further enhance stakeholder involvement and understanding.
- Organizing **in-person meetings in key regions or case study locations** allows for direct interaction with stakeholders, offering updates on progress and hands-on training on newly developed tools. These meetings should include interactive discussions and structured feedback collection to refine project's outcomes.
- **Study visits** are also an excellent way to provide stakeholders with real-world insights by showcasing relevant applications, facilities, and processes.
- Creating **dedicated online communities**, such as LinkedIn groups, is also a valuable strategy to foster discussions on related topics as well as to enhance collaboration and knowledge sharing.
- Maximizing outreach also involves **participating in external initiatives**, such as focus groups, mutual learning workshops, and collaborative training sessions. Engaging with external surveys or co-hosting conference booths with related projects can further amplify impact.
- **Public awareness campaigns** play a key role in making complex topics accessible to a wider audience. One successful method is to create interactive

content such as a social media quiz to educate the public on bio-based products while directing them to additional learning resources on the project website.

- Another approach is **publishing articles through media partnerships**. A structured series of articles featuring key stakeholders can provide multiple perspectives on the project's significance, from consumer groups to policymakers and industry representatives. Expanding outreach through non-traditional media, such as radio programs, can also be highly impactful.

5.2.4 Capacity building

Including most of the above-mentioned activities, to ensure the transferability and replicability of project outcomes, capacity-building activities have been designed to facilitate knowledge exchange and stakeholder engagement. Thus, a collaborative approach with related initiatives has been applied to further enhance impact, which is described in the following.

Capacity building activities	
Leaflet	Developing high-quality, accessible materials is essential for effective knowledge dissemination. Making such materials available both in print and as downloadable PDFs accessible through easy-to-use QR codes. Additionally, translating materials into multiple languages helps engage a broader audience and facilitates uptake in different regions.
Stakeholder factsheet	A stakeholder factsheet - available both online and in print - can serve as a quick reference guide. To enhance inclusivity, translating the factsheet into relevant languages ensures better engagement with diverse audiences. Providing stakeholders with a clear and concise overview of participation opportunities is also critical.
Workshops & training sessions	Workshops and training sessions should be integrated into well-known local events such as trade fairs and expos, bio-based forums or circular economy initiatives to introduce and validate tools with relevant stakeholders. For example, targeted sessions can be conducted to familiarise participants with the BIT tool, ensuring practical uptake and feedback-driven improvements.

Online resources	To further support knowledge transfer, it is beneficial to create online resources that simplify complex project concepts. Developing a dedicated FAQs & Glossary page on the relevant website ensures that key terms and methodologies are easily accessible. Promoting such resources through social media can further expand reach and encourage engagement beyond the immediate project community.

By implementing these strategies, projects can enhance the usability of their outcomes, facilitate stakeholder engagement, and ensure that their findings remain relevant and accessible beyond the project's duration.

5.3 Step 3: Identify your biological feedstock flows and resources

As far as the more technical aspects are concerned, an important step is to evaluate the sufficient availability and quality of biological resources within a local and regional area. Therefore, Step 3 focuses on identifying and quantifying the types of available resources, prior to their sustainability and circularity assessment, to replicate/transfer the BioReCer outcomes.

5.3.1 Identification of biological feedstock flows, resources and uses

One of the main steps in replicating BioReCer results is assessing the available biological resources. To this end, the following steps should be applied:

Biological feedstock selection commonly requires the following steps:

- Initially, it is crucial to identify (i) the **geographical location**, (ii) **proximity to consumption/use point**s, and (iii) the **availability of biomass resources** in the local area during the early stages of bio-based value chains development. This ensures the feasibility of the project at the local level.
- The second step is to identify the **physical and chemical properties** of the biomass to determine its suitability for the intended purposes. These data can be acquired from databases, which offer reliable estimates of such properties, contact with local stakeholders, who may have relevant data, or by performing specific analysis, which is recommended, as in some cases the properties of biomass can vary due to location, seasonality or origin. These analyses offer

insights into the quality and composition of the biomass, helping to assess its suitability as a feedstock.

When investigating the availability of biomass, several factors must be considered to ensure a reliable and sustainable supply:

- **Types of Biomass and Seasonality:** the availability of certain types of biomass is seasonal. For example, agricultural residues (e.g., straw, corn stover) serve as valuable sources of biomass, varying significantly in availability based on local agricultural practices. These resources exhibit clear seasonal fluctuations, with harvesting and collection typically concentrated in specific periods of the year. For effective planning and ensuring continuous supply, it is critical to understand the type of biomass available in each region and its seasonal collection patterns. This insight is essential for securing a stable feedstock supply for non-energy applications such as soil amendments or bio-based product manufacturing.
- **Physicochemical Characteristics and Composition:** The physicochemical properties of biological feedstocks - such as energy content, moisture levels, ash content, and chemical composition - differ widely depending on the biomass source. These factors significantly impact the biomass suitability for various applications, including use in biodegradable products, soil enhancement, and raw material processing. Biomass with lower moisture content and minimal ash is often preferred for such uses, as it ensures higher quality and performance.
- **Pre-treatment and Supply Chain Logistics:** Biomass pre-treatment plays a pivotal role in its utilization. Availability of effective supply chain management ensures that biomass is pre-treated efficiently, minimizing potential losses and maximizing its value for non-energy applications.
- **Storage and Year-Round Availability:** Given the seasonal nature of some types of biomass, such as agricultural, proper storage infrastructure is necessary to maintain a stable supply throughout the year. Well-designed storage systems prevent degradation of biomass due to moisture absorption or biological degradation, preserving the quality of the material.
- **Legislative and Regulatory Frameworks:** The utilization of biomass as a raw material is subject to various national and regional regulations, which govern sustainability standards, environmental impacts, and land use practices. Compliance with these regulatory frameworks is crucial for ensuring responsible sourcing and processing of biomass, ensuring that the environmental impacts of utilizing biomass are minimised. Understanding the legislative landscape is vital

for making informed decisions about the sourcing, processing, and utilization of agricultural biomass in line with sustainability goals.

5.3.2 Data collection

Data collection is a critical point for the credibility of the analysis and transferability of the results. In general, data can be retrieved from the following sources:

- Primary data from companies and other relevant stakeholders
- Communication with local experts
- Regional and national statistics
- Credible databases (e.g. Ecoinvent)
- Peer reviewed literature

5.3.3 Data quantification and representation

As a next step, the data quantification and the results representation aim to link additional information to the material flows, enabling sustainability assessment of waste and by-products to bio-based applications conversion. To this end, MFA can be applied to facilitate an understanding of the interconnections between resource origins, valorisation pathways, and end-use applications. It also delivers quantitative data on material and energy inputs and outputs, resource consumption, and stock levels. Thus, this step enables the systematic mapping of material and substance flows, offering essential insights into resource efficiency, product development, waste management strategies, environmental planning, and the assessment of environmental impacts (Huang et al., 2012; Ning et al., 2025; Raj et al., 2024). Typically, Sankey diagrams are used for the representation of the results of by-products, residues, and wastes as well as and their reutilization in biomass conversion and application processes. In this way, the comprehensive understanding and assessment of the interactions, resources efficiency and circularity across bio-based sectors is facilitated. The analytical steps applied for an MFA are schematically illustrated in Figure 12.

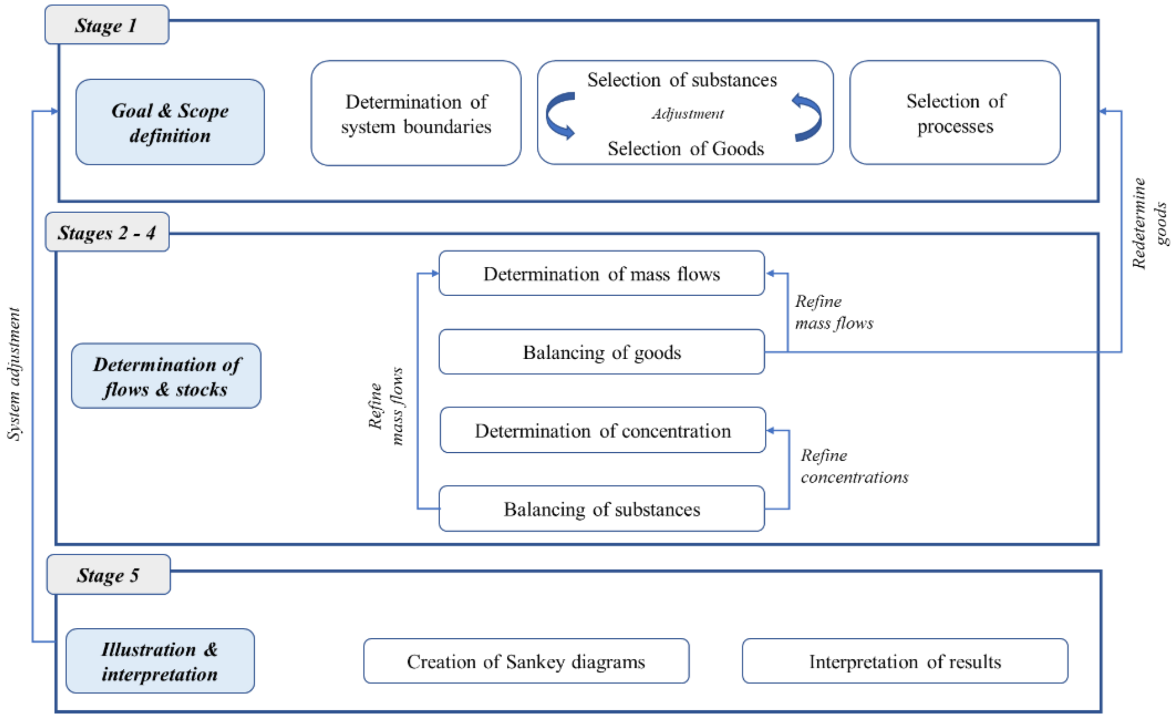

Figure 12: Methodological steps to perform an MFA (adapted from (Brunner & Rechberger, 2004)).

The applied MFA methodology comprises the following stages and steps:

- **Stage 1: Goal and scope definition**

  1.1 *Definition of system boundaries*.

  1.2 *Determination of the biological feedstocks flows* that will be investigated.

  1.3 Determination of the mass unit employed in the analysis. In general, the development of a standardised and uniform level of aggregation for the different flows is a crucial task since statistical and database aggregation levels exhibit a significant degree of heterogeneity. To facilitate additional analysis, the data should undergo a process of aggregation to a standard level of granularity that was deemed both comprehensive and informative for the research study at hand (Kalt, 2015a).

  1.4 Literature research and review of statistical data for the selection of primary data sources.

  1.5 *Accumulation of basic information for each feedstock*, including functional specifications, seasonality, main barriers (i.e., legal, social, regulatory).

  1.6 Establishment of a preliminary flow diagram to initially visualise the flows, their interactions, their sources and destinations. The relevant processes, resources and products should be precisely identified and interconnected. Visualizing the value chain in a simplified way is a primary task in the context of an MFA.

- **Stage 2: Investigating the origin of each biological feedstock**
  2.1 Identification of each feedstocks source.
  2.2 Identification of the value chain related to the production of the biological feedstock and determine the related flows and stocks.
  2.3 Determination of the quantity of each flow. To estimate the volume of each feedstock and create a comprehensive database, the required information should include: (i) statistical data concerning the quantities of biomass residues from national and/or regional databases, relevant literature, statistical research, etc.; and (ii) Coefficients to convert the available data to quantity of the selected feedstock (e.g. crop to residue coefficient, sewage sludge per capita, etc.). This effort involves an in-depth examination of related literature and statistical data to ascertain appropriate conversion factors. The coefficients employed can be tailored to each value chain investigated.
  2.4 Estimation of the imported quantities of biomass streams, based on data from official databases.
- **Stage 3: Investigating the fate of the biological feedstocks**
  3.1 Identification of the main uses of the selected biological feedstocks. More specifically, this step examines the processing stages of the biological feedstock, until it exits the system. Thus, for every application corresponding to a dedicated feedstock, the following steps are implemented:
  a. Identification of the value chain stages and determination of the related flows and stocks. Typically, an MFA focuses on the direct material flows associated with the extraction, processing, use, and end-of-life phase of a particular material, as well as imports and exports for different life-cycle stages.
  b. Quantification of the biomass in each stage, utilizing the appropriate conversion factors. Similarly, in the primary stages, the conversion factors will be obtained from the literature, statistics, etc.
  c. Mass balance is applied to each processing stage (Hendriks et al., 2000b). Material balances are executed on procedures for which data are not available, employing the principle of mass conservation. Based on this, the quantity of mass entering a system equals the amount of mass exiting it. If necessary, the outcomes may be integrated into both static and dynamic models.
  d. Investigation of the End-of-Life options and retrieval of quantitative data.
  e. Quantification of the biological feedstock destined for exports.
  f. Calculation of the losses based on literature data and mass balances.
- **Stage 4: Validation and filling of data gaps**
  4.1 Revision of the biomass flow diagram. In this stage, the final configuration of

the diagram is established. Certain streams of the preliminary structure (identified in step 1.6), that correspond to separate industry sectors may be merged, due to limitations in data availability and uncertainties related to the origin or destination of the associated flows. Data gaps that may be identified are subsequently filled by means of reliable assessments and mass balance considerations (Kalt, 2015a)

- **Stage 5: Representation of results**
  5.1 *Accumulation of data and creation of a database. A tabular form is recommended.*
  5.2 *Graphic representation. Dedicated diagrams depict the biomass flows along with corresponding values, thereby facilitating the examination of different applications of a particular biomass flow, allowing data integration from multiple sources, showcasing the evolution of biomass flows over time and comparisons between different geographical levels (e.g., between the EU countries or different regions), and finally illustrating both synergies and competition in the use of biomass streams. To this end, the adoption and implementation of Sankey diagrams has been a common practice. More specifically, a Sankey diagram serves as a graphical tool for delineating the pathways of biological feedstock flows amidst various processes, explicitly distinguishing the sources from the distinct usages or applications they serve (Marques et al., 2020a)*
  5.3 *Interpretation of results, discussion, and conclusions. The final phase of this methodology entails the interpretation and discussion of the findings, followed by the drawing of conclusions. The interpretation of the MFA results entails a comprehensive assessment of the loading quantities, the relevance of stocks, and a comparative analysis of the results in relation to environmental benchmarks, sustainable metrics, or alternative evaluation methods (Hendriks et al., 2000a).*

Overall, the MFA provides a comprehensive overview of the material flows and a valuable basis for the management of resources and their valorisation in the value chain. This information is critical for the effective utilization of resources, the recovery of materials, energy or components and their retention in the value chain in alignment with the principles of circular bioeconomy. The abovementioned process can be conducted at various levels (e.g. at a national, regional, industrial, enterprise, and business site level) (Choi et al., 2024), and in parallel, it can be adapted to different sectors, and geographical scale to support the characterization of biomass flow balance and analyse the interaction in biomass demand and consumption.

To complement the material flows, quantitative information on the raw material and energy inputs along with the generated by-products, emissions and waste streams should be also provided, leading to the creation of complete inventories. To this end, an extended I/O table can summarise in a compact and uniform way the quantitative information that describes each defined value chain, allowing the comprehensive record of direct and mainly indirect flows. More specifically, all the inflows (i.e. the main feedstocks, additional raw materials, resources and utilities) and outflows (referring to the material streams, waste, losses and emissions) are provided. A description of the indicative structure and components of the extended I/O tables is provided below (Figure 13).

- **Process stage**: The process stage constitutes an aggregation of stages of the value chain that serve the same purpose (e.g., pretreatment of the material, transportation, etc).
- **Inputs**: Input is defined as what enters each process stage. For our case the inputs are the main flow (total or component), the resources, raw materials and energy (electricity, fuel etc) needed. The main flow refers to the main biological feedstock of interest. Due to the importance of this flow, an additional level of detail is provided with specifications about its composition, moisture content and dry mass.
- **Outputs**: output is defined as what exits each process stage. For example, outputs are main flow (total or component), the primary products, co-products or other by-products, the generated waste and the losses, the emissions (direct from combustion or indirect from electricity).

Concerning all the inputs and outputs of the main flows the masses (in kg) are expressed in dry mass (DM) and wet mass (WM), while the moisture content (MC) is also provided, as shown in Figure 13.

Process stage	Description	Input / Output	Flow No	Flow characterization (Level 1)	Material specification (Level 2)	Unit	Total quantity		
							Main flow		
							WM	*MC*	*DM*
CO-100	Storage	Input	101	Energy	Diesel	kg			
		Output	102	Main product	Product A	kg			
		Output	103	Emissions (direct)	GHG	Kg CO_2-eq			
CO-200	Transportation	Input	201	Energy	Diesel	kg			
		Output	202	Main flow	Product B	kg			
		Output	203	Emissions (direct)	GHG	Kg CO_2-eq			

Figure 13: Example of the I/O tables.

The steps that are followed for the performance of the current analysis and the development of an I/O Table are:

1. Definition of the system boundaries and identification of the value chain stages.
2. Estimation of the quantities of available biological feedstocks generated in the areas under analysis.
3. Acquisition of data for the main biological feedstock flows, material and energy consumption through the value chains.
4. Performance of the mass balances and MFAs, where relevant.
5. Estimation of emissions based on the emission factors coefficients.
6. Processing of data and creation of the extended data tables.
7. Visualization of the results and interpretation.

The outline of the methodological steps refers to the generic version of the table shown in Figure 13, which can be further modified to adapt to the specific conditions of each case study. The tables' structure could also be modified depending on the specificities of the value chain.

5.4 Step 4: Choose your indicators

The circular economy practices introduced by BioReCer, target to address the environmental impact of production and waste management using secondary bio-based raw materials. To this end, Step 4 includes the implementation of a systematic methodology for monitoring and evaluating the bio-based solution's impact. The integrated project's approach is formulated in a list of sustainability and circularity indicators (as presented in D2.3). For capturing all the evaluation aspects included, a set of relevant and context-specific indicators needs to be defined and carefully selected. These indicators serve as measurable benchmarks, which enable tracking the success of the applied approach / process, identifying areas of improvement and ensuring that the outcomes are aligned with the broader sustainability and circularity principles.

5.4.1 Selection of sustainability and circularity indicators

5.4.1.1 Set of sustainability indicators

In the last decade, the definition of sustainability indicators has been conducted at different levels (Kumar & Joshi, 2022). General lists of indicators serve as an evaluation framework, but they must be practical enough to allow efficient and feasible evaluations. Therefore, a framework of indicators was developed (with the procedure shown in Figure 14), which is solid as required in existing certification systems and policies, such as the EU taxonomy.

Figure 14: Representation of the different stages of the roadmap for the selection of sustainability indicators.

In general, for the selection of a reliable set of sustainability indicators the following process should be followed:

- **Definition of the indicator**: The first step in selecting a reliable set of indicators is to clearly define what is meant by "indicator". This is due to the diversity of indicator **types**, which can be qualitative, quantitative or both or even performance, descriptive and composite (Lähtinen et al., 2014).
- **Description of the goal of the indicator**: Once their characteristics have been established, the next step is to determine the **objective and scope** of each

indicator (Pavlovskaia, 2014). Some may be general, while others may be sector-specific or cover only part of the value chain.

- **Critical review analysis**: After defining the objectives of the indicators, it is crucial to carry out a **critical analysis**. In the scientific field, a systematic review based on keywords can be an appropriate methodology (Lähtinen et al., 2014). Indicators are found in academic literature, in business, government and institutional reports, as well as in certification systems. Therefore, it is necessary to complement the compilation of scientific indicators with the analysis of official documents and current regulations (Ares-Sainz et al., 2025) and select the most relevant to the specific case study/value chain.
- **Alignment with strategies, actions and legislation demands**: The result of this process should be a set of indicators aligned with well-defined criteria. First, political and legislative objectives should be considered, selecting indicators that allow the performance of government actions to be measured. For example, alignment with the SDGs or the EU taxonomy, but also with specific regulatory frameworks for certain sectors, such as the bio-based materials approach of the BioReCer project (Gebara et al., 2024). To refine the list and avoid the elimination of relevant indicators, their ability to describe the outcomes of decision-making systems should be assessed according to their scale. In addition, the practical feasibility of their use should be considered, including an economic evaluation of the labour costs associated with their application.
- **Stakeholder engagement**: For the indicators to be useful in decision-making, they must reflect the main concerns of the actors involved. Therefore, it is advisable to draw up questionnaires to identify and prioritise these concerns. Stakeholders´ opinions are especially important for ranking the indicators and aligning them with the requirements of the framework on which they will be based (Mascarenhas et al., 2015).
- **Classification of the indicators**: Finally, indicators should be classified according to their relevance. Some will be directly related to legislative thresholds, while others will have a more informative function. They can be divided into static indicators, which fully describe the system from the first moment of evaluation, and dynamic indicators, which allow for analysis over time. In addition to basic, regulation-oriented indicators, advanced indicators capable of anticipating future needs should be included (Estévez et al., 2025). These, in turn, can be static or dynamic, depending on whether they already have reference values or if they simply provide information on the performance

of the system.

5.4.1.2 Set of circularity indicators

Along with the sustainability indicators, a comprehensive set of circularity indicators has been developed (D2.3) to evaluate the intrinsic circularity performance of bio-based products and processes. These indicators are designed to be applied across the product life cycle – spanning raw material acquisition, production, use, and end-of-life stages – while addressing the specificities of biological feedstocks and the dual nature of technical and biological cycles. The methodology and full indicator set follows a structured selection framework based on three principles: (i) alignment with ISO 59020 standards on circularity performance assessment, (ii) relevance to circular economy (CE) objectives in the bio-based sector, and (iii) applicability to both technical and biological cycling pathways.

For replicability and transferability, these circularity indicators serve as key tools to benchmark and guide the adaptation of circular practices in different regional and operational contexts. They enable stakeholders to monitor the use of renewable and secondary resources, efficiency in process function inputs (e.g. energy, water, chemicals), cascading use of biomass, and biological/technical end-of-life scenarios. Moreover, qualitative indicators and reporting templates for hazardous substances are included to ensure safe cycling and avoid risk accumulation, addressing gaps in current certification schemes.

In general, the following structured approach can be adopted for the selection of appropriate circularity indicators, specifically tailored to the assessment of bio-based products in alignment with both standardised frameworks and sector-specific CE objectives:

1. **Alignment with standardised frameworks:** Indicators should first be evaluated based on their alignment with established circularity frameworks, such as the ISO 59000 series (especially ISO 59020). This ensures consistency, comparability across assessments, and enhanced stakeholder credibility.
2. **Relevance to bio-based circular economy objectives**: Given the unique characteristics of bio-based products, indicators are assessed for their ability to reflect prioritised CE objectives such as increasing the share of renewable resources, resource efficiency (including residue and waste use), cascading use,

and material recirculation.

3. **Suitability across product life cycle**: Selected indicators must be appropriate for different life cycle phases (input, use, end-of-life) and specific product types (durable vs consumable). Consideration is also given to whether the product follows a biological or technical cycling pathway, ensuring accurate and context-specific assessment.
4. **Elimination of double counting and clarification of definitions**: To avoid redundancies and overlaps (e.g. between renewable, recycled, and reused content), indicators should be differentiated between pre- and post-consumer recycled content and redefine "renewable" based on verifiable sustainability criteria (e.g. replenishment rates, certifications, etc.).
5. **Inclusion of hazardous substance considerations**: Hazardous substances are not directly captured by ISO indicators but are critical to circularity and safety. Qualitative indicators and data reporting requirements are integrated to ensure tracking and management of hazardous substances throughout the product life cycle.
6. **Indicator typology and application**: A typology matrix (D2.3) is used to assign indicators to appropriate life cycle phases and product scenarios. This ensures clarity in application and facilitates effective monitoring of circularity progress at the product level.

The selected indicators are grouped into five main categories:

- **Material input indicators** (e.g. virgin renewable content, pre/post-consumer recycled content)
- **Circular production indicators** (e.g. energy and water intensity, circular process-function materials)
- **Use-phase indicators** (e.g. product lifetime extension, reusability potential)
- **End-of-life indicators** (e.g. actual biological recirculation, recyclability rate)
- **Cascading and value retention indicators**, such as the Biomass Utilization Contribution and the Value-based Biomass Utilization Contribution, which account for feedstock valorisation across co- and by-products.

While several indicators are transferable as-is, others may require adaptation depending on the characteristics of the bio-based system, local infrastructure, and data availability. For instance, the assessment of cascading use or biological recirculation may vary based on the end-of-life treatment options and regulatory context in a new region. Similarly, the verification of feedstock renewability depends on the availability of certifications and monitoring systems. Therefore, the proposed indicator set is intended not only as a benchmarking tool, but also as a flexible foundation that allows for contextual a during replication.

5.4.2 Bio-based value chain assessment

The BioReCer Sustainability and Circularity Assessment Framework has established and defined a set of requirements and indicators for the bio-based sector to help determine the sustainability and circularity of biological feedstocks. This can be applied in different sectors that generate these resources, such as agriculture, forestry, fishing or waste management.

The main steps for the application of the BioReCer Sustainability and Circularity Assessment Framework and the assessment of a bio-based value chain are described below:

- **Understand the context:** an important first step is to understand how the Sustainability and Circularity Assessment Framework applies to the context and specifics of an organisation and their products. There might be cases where some basic requirements do not apply to a specific organisation or product and by means of proper justification can be excluded when applying the BioReCer Sustainability and Circularity Assessment Framework.
- **Calculate the circularity indicators:** once the Sustainability and Circularity Assessment Framework has been adapted to the organisation and product, the circular indicators can be calculated. In this case two scenarios must be calculated. The first is the baseline scenario, which will determine where the organisation and product is at this moment regarding their circularity. The second scenario is the best performance scenario, i.e., the best possible practical maximum that can be achieved for the product and the organisation in terms of circularity. Having the start and end points allows the organisation to establish a road map to follow based on the continued improvement principle.

Within the scope of the project, four types of circularity indicators have been defined to measure different aspects of a product life cycle (Figure 15), ensuring a complete evaluation of its circularity.

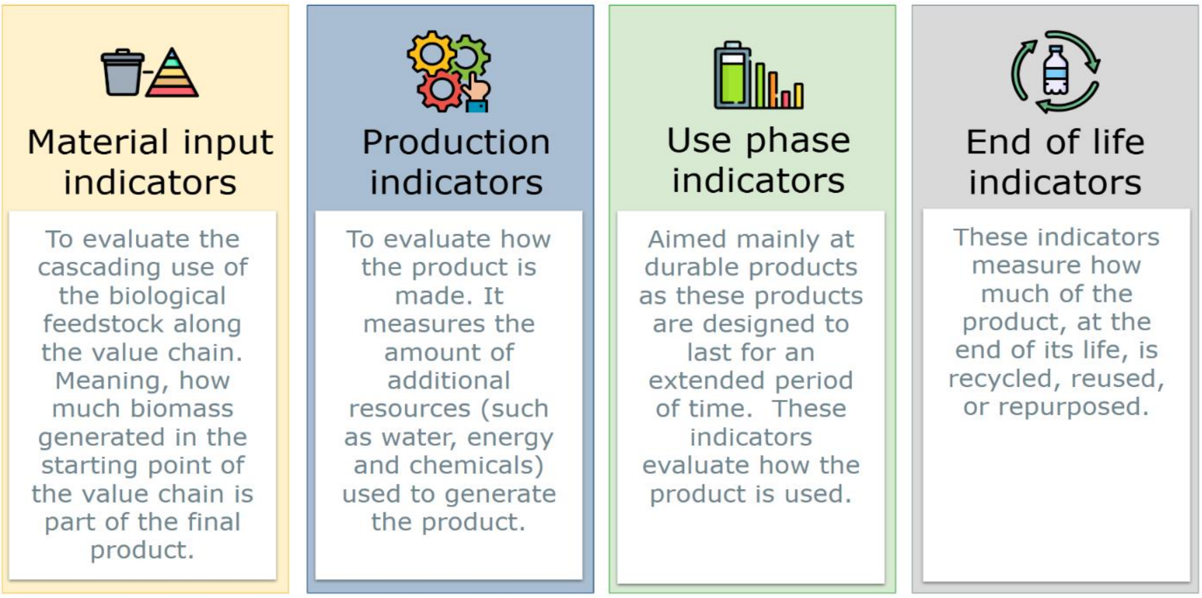

Figure 15: Type of circularity indicators across a product life cycle.

Also, the different actors that are involved in a bio-based value chain were defined as follows: i) primary producers; ii) waste producers; iii) intermediate producers; and iv) final producers (Figure 16).

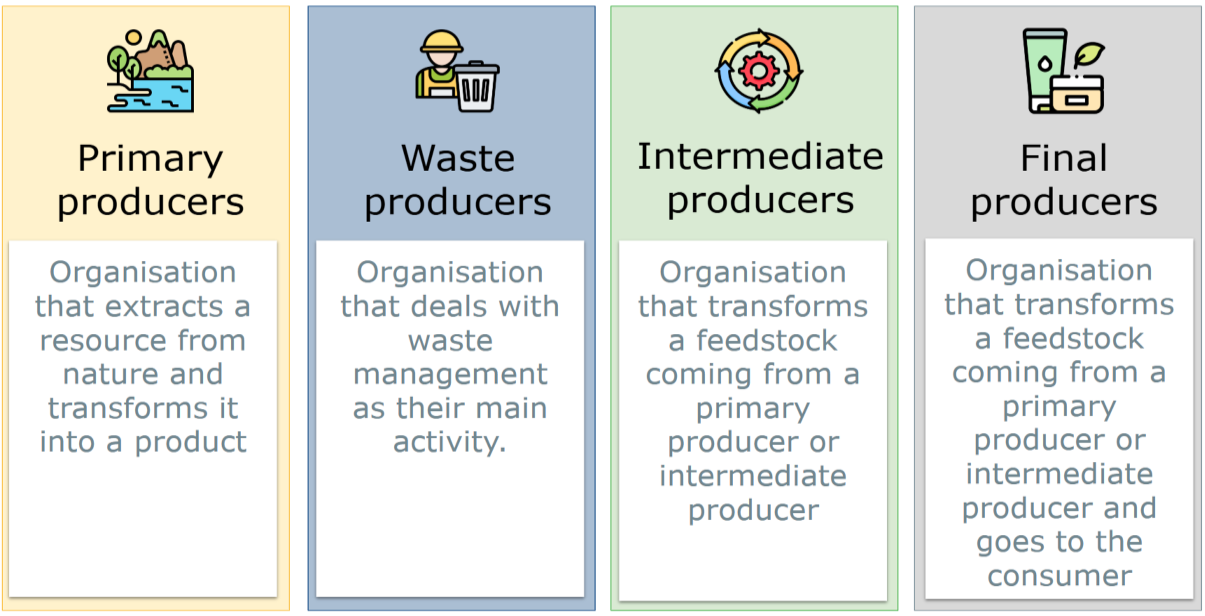

Figure 16: Types of actors in the bio-based value chain.

To calculate the circular indicators a series of steps need to be followed (Figure 17):

1. Identification of the main bio-based product to be considered/evaluated.
2. Identification of all other bio-based co-products that are generated. Residues are also included here.
3. Identification of all biological and fossil feedstocks necessary to produce the main product, as well as the by-products and residues resulting from the process.
4. Identification of your position (i.e., type of actor according to Figure 16) in the value chain. It should be noted that: i) you are a primary producer if your feedstock comes from natural sources; and ii) you are a waste producer if your primary activity is waste treatment/management; and iii) you are an intermediate producer or final producer when none of the above apply to you.
5. Quantification and characterisation of all your flows. This includes feedstocks, product, co-products, residue, resources (water, energy, chemicals, etc).
6. Review the applicable indicator equations. Gather any additional information necessary for calculation.
7. Calculate all applicable indicators. Material input and production indicators are calculated by every type of actor in the value chain. Intermediate and final producers are responsible for calculating the use phase and end-of-life indicators. Primary producers, being at the start of the value chain, can access the required information more easily. On the contrary, intermediate and final actors, at more advanced steps in the supply chain, will need to contact their feedstock provider to support the calculation of the previous step(s) in the chain. Likewise, although waste producers are also at the starting point of a value chain, they also may need to request information about their input feedstocks, depending on the type of waste management they provide.

Finally, a key aspect when measuring circularity is understanding how biological feedstocks are used throughout the value chain. The above-mentioned steps need to be complemented with an overall understanding of the entire value chain. Thus, generating a flow diagram of the value chain is a visual way of understanding the inputs, outputs and flows of a given value chain. The level of detail will depend on the information available. As a minimum, the organisation preparing to apply the BioReCer Sustainability and Circularity Assessment Framework must identify their position in the value chain as well as the steps that precede and follow themselves.

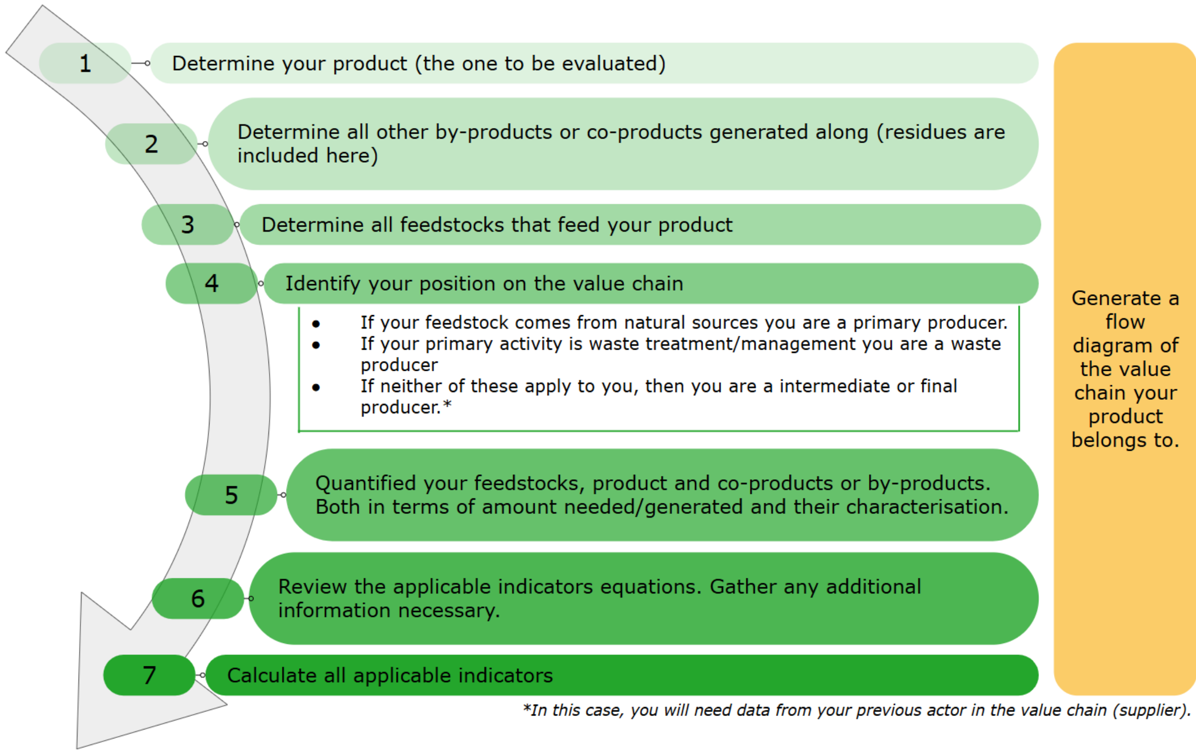

Figure 17: Steps to calculate quantitative indicators.

5.5 Step 5: Integration of BioReCer Sustainability and Circularity Assessment Framework into existing certification schemes

Certifying a bio-based system (product, process, etc.) is a complex process that depends on many factors. The sourcing of raw materials and biological resources, the production methods applied, and the lifecycle of the product are key components that need to be considered to ensure compliance with the standards set by the certification scheme. Early integration of the abovementioned considerations will guarantee that the product or service aligns with the sustainability goals outlined by the certification body. In this context, a successful integration of the BioReCer Sustainability and Circularity Assessment Framework into established certification schemes contributes to ensuring transparency, fostering consumer trust, and supporting the transition to more sustainable practices within biological resources value chains.

5.5.1 Steps for BioReCer certification application

Building on this objective, the BioReCer Sustainability and Circularity Assessment Framework was developed as a complement to existing certification schemes, therefore, its interlinked set of sustainability and circularity requirements, along with quantitative indicators, is designed to close gaps from the main certification. This approach contributes to the compatibility with established schemes and expands their scope with deeper insights into sustainability and circularity criteria. A structured approach to supporting existing certification schemes is provided by the BioReCer Sustainability and Circularity Assessment Framework. However, this requires an adoption process, in which the key aspects of alignment between BioReCer and the existing certification schemes should be assessed.

The following steps (Figure 18) serve as a roadmap for smoother adaptation:

1. **Credibility and reliability of certification scheme**: As the BioReCer Sustainability and Circularity Assessment Framework is designed to complement existing certification schemes, it is essential that these schemes are both credible and reliable. The key characteristics that a certification scheme should demonstrate to integrate the BioReCer Sustainability and Circularity Assessment Framework are outlined below.
    - It is an independent third-party system with a clear distinction between the standard owner, certification bodies and companies: Certification schemes should have processes that involve an independent and unbiased third-party organization conducting audits, assessments, or inspections to verify compliance with the defined standards.
    - It has well defined and transparent Standards and Criteria: Certification schemes must have clear, measurable, and specific standards. All the requirements and processes involved in obtaining certification are openly accessible to companies, stakeholders, and the public.
    - It is developed and managed through a multistakeholder process: Certification schemes involve the participation of a diverse group of stakeholders in the development, implementation, and review of the standards and processes. This may include industry representatives, environmental groups, consumer organizations, government bodies, and other relevant entities.
    - It has a regular monitoring system in place: Certification schemes must ensure that the company continues to meet the requirements even after certification is granted.
    - It has an integrity program and sanction system in place: Certification schemes should have processes to detect and prevent fraud, conflicts of interest, or any actions that undermine the credibility of the certification. In case of any mishap, actions and penalties such as suspension or revocation of certification must be clearly defined.
2. **Benchmark against BioReCer Sustainability and Circularity Assessment**

Framework: The benchmarking process aims to identify alignment of the BioReCer Sustainability and Circularity Assessment Framework (principle, criteria, requirements, and indicators) with the main certification scheme. Therefore, the certification scheme must conduct a benchmark of their existing requirements against the BioReCer Sustainability and Circularity Assessment Framework. The certification schemes should refer to the practical guidance document (developed under WP4/D4.3). This document provides an in-depth understanding of the requirements of the BioReCer Sustainability and Circularity Assessment Framework as well as evidence and documentation required for compliance. Based on the results of this exercise, a certification scheme can identify requirements that are already aligned with the BioReCer Sustainability and Circularity Assessment Framework and the new requirements that must be integrated into the scheme.

3. **Pilot testing**: Use case testing is essential to evaluate the practicality and usability of the BioReCer Sustainability and Circularity Assessment Framework and its accompanying audit checklist under real operational conditions. This step ensures that the BioReCer Sustainability and Circularity Assessment Framework can be effectively applied within certification processes. Onsite use case assessments help identify unforeseen challenges, such as unclear instructions, difficulties in collecting the required data, or inconsistencies that may hinder certification bodies or auditors from verifying BioReCer requirements.
4. **Alignment of audit procedure**: Aligning audit procedures means that the processes followed during audits to assess the requirements of the main certification scheme, as well as the requirements of the BioReCer Sustainability and Circularity Assessment Framework, should be standardised while maintaining the integrity of the certification scheme. The approach to alignment may vary between schemes. Each scheme should determine the most suitable procedure based on its internal processes. The following are examples of how this alignment might be achieved:
   - Adjust or update the compliance levels for requirements that are aligned between the main certification scheme and the BioReCer Sustainability and Circularity Assessment Framework.
   - New requirements introduced by the BioReCer Sustainability and Circularity Assessment Framework can be added as additional criteria to the audit documents of the main certification scheme.
5. **Engage stakeholders**: An effective stakeholder engagement process is essential when adding requirements to the certification standard as this ensures that the new requirements align with the needs and expectations of all relevant groups (e.g., industry representatives, regulatory bodies, NGOs, consumers, and businesses).
6. **Train the accredited certification bodies (CBs)**: When new requirements are added to an existing certification scheme, it is crucial that the accredited CBs are

properly trained to understand and implement the new elements in their assessments. Following the standard procedure of the main certification scheme, CBs must be trained and made familiar with the audit procedure aligned with the BioReCer Sustainability and Circularity Assessment Framework.

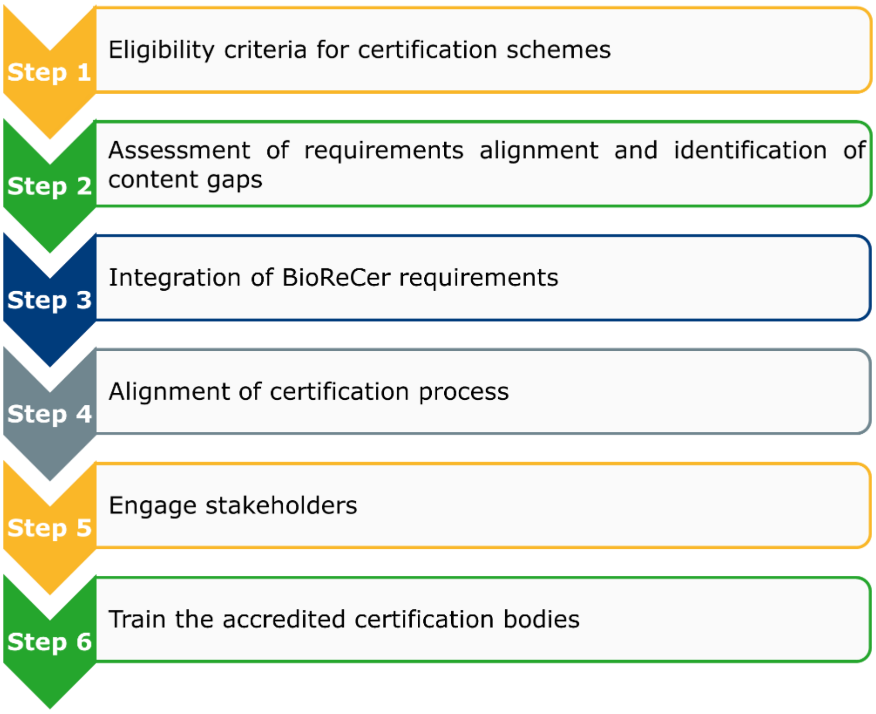

Figure 18: Process for integration of the BioReCer Sustainability and Circularity Assessment Framework into current certification scheme (adapted from D4.3)

The abovementioned approach, along with the feedback and lessons learned from the use case assessments, provided valuable insights that supported the iterative refinement of both the BioReCer Sustainability and Circularity Assessment Framework and the verification guidance document. As ISCC PLUS is a key reference scheme for the project, the testing and validation were carried out through use case assessments conducted in accordance with the ISCC PLUS audit procedure. The insights gained from integrating BioReCer with ISCC PLUS can further inform and guide future applications.

5.6 Step 6: Application of the BIT

The stepwise journey ends with the use of the BIT. Once the new framework has been established with the above steps, it is time to set up the BioReCer tools. This could involve adapting the interface tools, creating the data model (new entities, new attributes, new indicators, new equations, etc.) and developing the data acquisition system. Figure 19 shows the BIT general architecture.

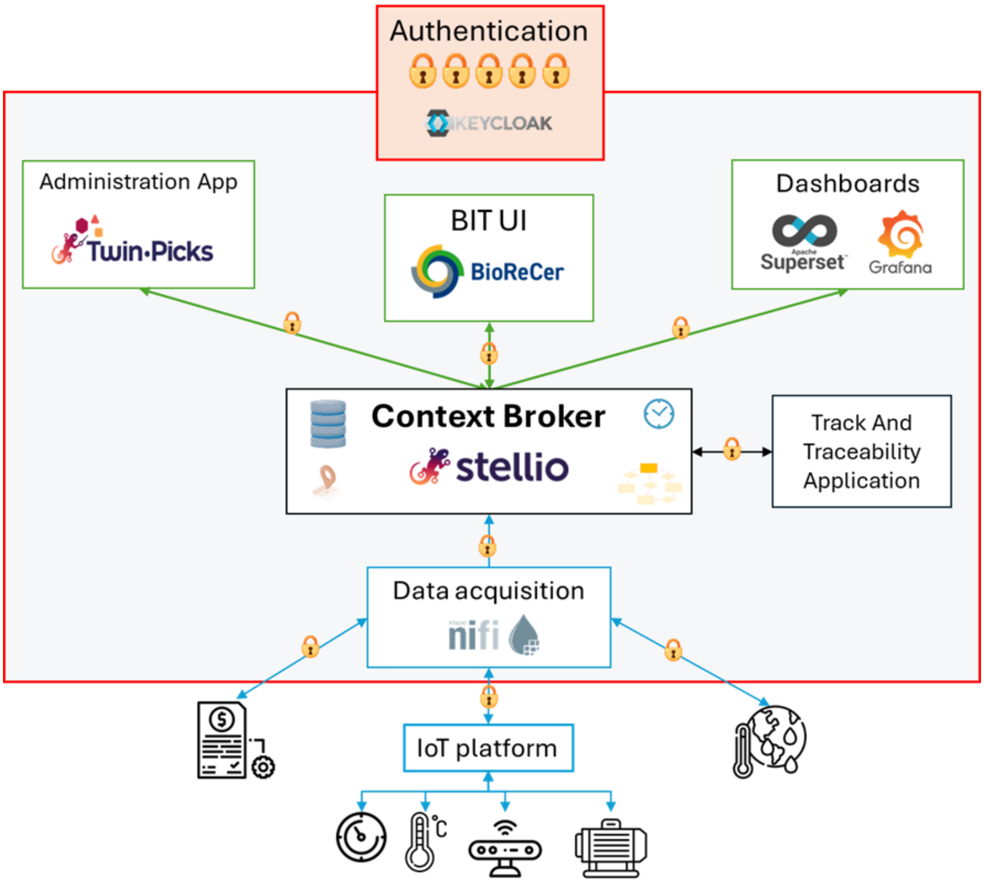

Figure 19: The BIT general architecture

The components that form BITAdvisor (WP5/D5.1, D5.2, D5.3) from the data and indicators it uses and how they are calculated, to the recommendations it provides through the analysis of these data and indicators, will have to be adapted to the new local context. Figure 20 depicts the infrastructure which must be replicated. Docker is utilised as the containerization solution for all components of the system. In Figure 20, each small blue box represents a component running within a container on a virtual machine. The Virtual machine for the dashboards is optional. Indeed, as of today a need for advanced data visualization has not been identified. It is important to note that for the BIT UI to be used, the knowledge graph (or data model) must be populated by entities into the context broker (Stellio). Within the BioReCer project, the provisioning is the dedicated role of the "Twin Picks" administration interface (Admin UI) that is used to ease the process. However, if the provisioning of entities can be automatically achieved by a new component, and later, automatically updated each time a product is transported for example, or is used as input or as output, etc., then the administration interface wouldn't be necessary.

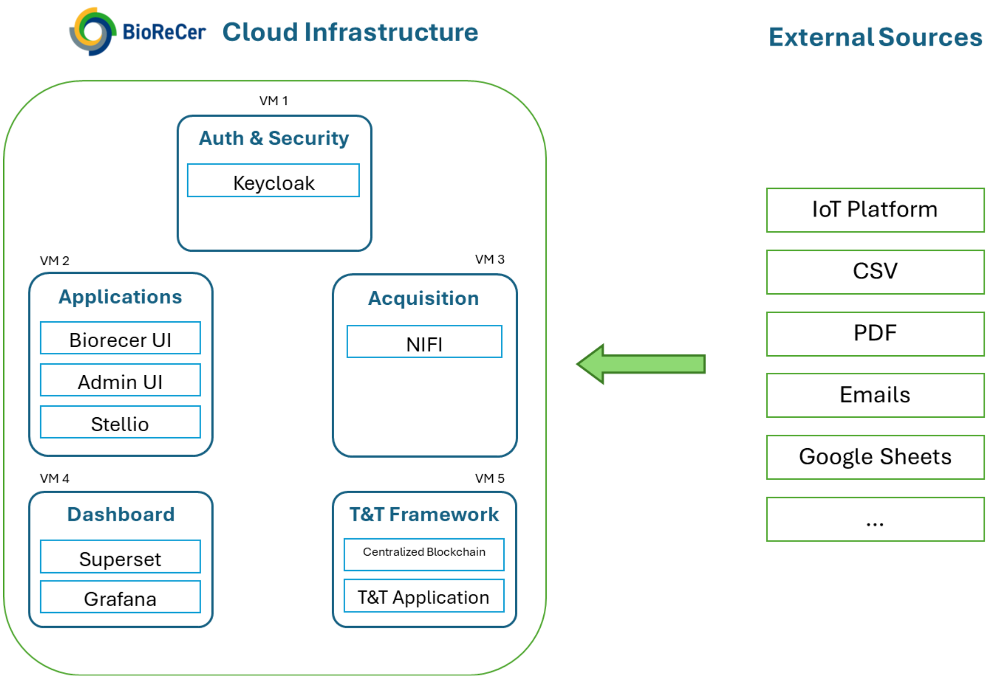

Figure 20: BioReCer Cloud Infrastructure virtual machines distribution

5.7 Make it happen!

To replicate or transfer BioReCer results, it is useful to consider the steps outlined before. In this regard, it is also important for the stakeholders involved to develop a roadmap that ensures all essential actions are well-thought out and taken into consideration. By following a series of indicative actions, as outlined in this report, a roadmap can be designed and facilitate the identification of how a bio-based initiative could turn into a sustainable and circular solution.

5.7.1 Roadmap towards building a circular bio-based value chain

The development of the Replicability and Transferability roadmap facilitates the effective transfer and replication of BioReCer solutions across different regions. The proposed roadmap, as described in the previous sub-sections is intended to be both comprehensive and adaptable, allowing for customization based on the specific conditions and needs of each target area. A detailed process flowchart is provided in Figure 21

Figure 21: BioReCer Replicability and Transferability roadmap

6 Demo case studies

6.1 BioReCer in other European regions

Expanding the BioReCer outcomes across different European regions is a key objective to promote harmonised sustainability practices within the EU's bioeconomy. To this end, a roadmap has been developed emphasizing on the use of BioReCer tools, and particularly MFA and I/O Tables, as essential instruments for systematic data collection. These tools support the assessment of the replicability and transferability potential of BioReCer results across various European contexts (Figure 22). A vital element of this replication effort was the BioReCer Case studies, where project partners and case study leaders were actively involved in testing and adapting the Sustainability and Circularity Assessment Framework to regional specificities, thus paving the way for their broader adoption across Europe.

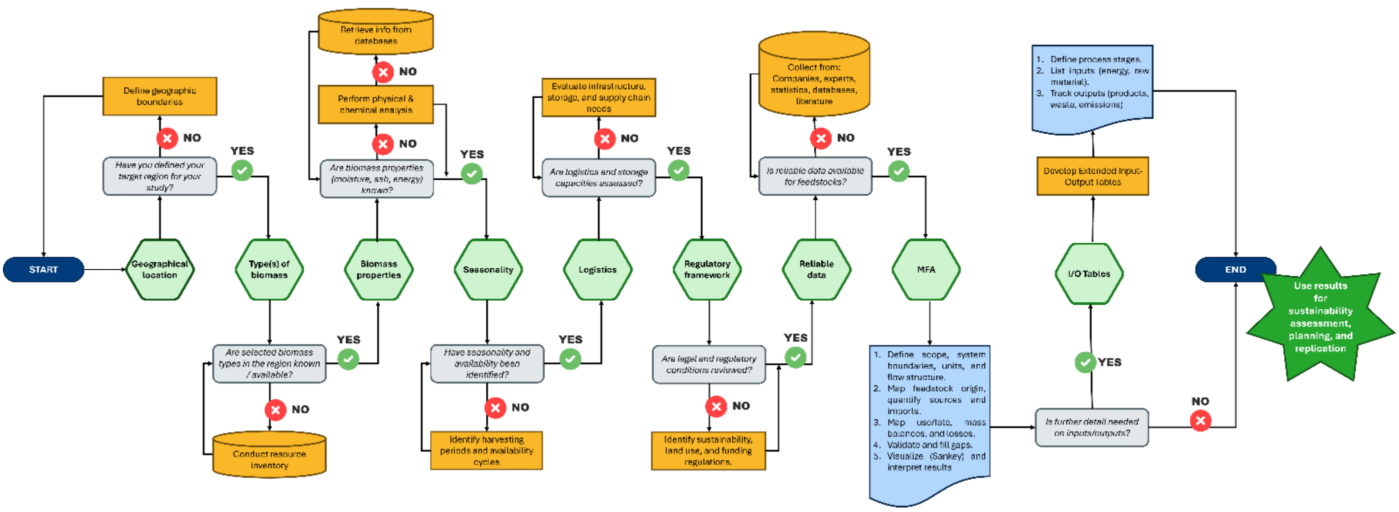

Figure 22: Replication of using MFA and I/O Tables in a nutshell

The core outcome of the Replicability and Transferability roadmap (Figure 22) is to create a bio-based system that ensures robust and harmonised data collection across different European regions, facilitating reliable assessment of sustainability and circularity, as well as enabling the effective replication and transfer of BioReCer results. Furthermore, comprehensive data collection supports the full utilization and functionality of the BIT tool, enhancing its effectiveness in decision-making and system analysis. Ultimately, this integrated approach contributes to the promotion and development of value chains based on secondary biomass, aimed at the production of high value-added products.

6.1.1 Replication analysis

The replication exercise aimed to evaluate the feasibility of applying BioReCer methodologies and tools, primarily MFA and I/O tables, across different European regions. Six countries were included in this assessment: Greece, Spain, Italy, Sweden, the UK, and Germany. The analysis focused on feedstock sectors similarly to project's case studies (agriculture, forestry, fisheries, and OFMSW and WWTP sludge) and considered the following replication steps: geographical mapping, feedstock identification, biomass properties, seasonality, logistics, regulatory framework, data availability, MFA construction, and I/O table development. Each step was assessed by local consortium partners in terms of replicability and the difficulty level required to implement it, based on data availability, as summarised in Table 1. This structured approach provided a comparative understanding of regional constraints and opportunities, highlighting both common challenges.

Table 1: Regional replication exercise

Stage	Step	Sector	Selected Feedstock*	Yes / No	Level of difficulty**	Comments
Geographical location	*Have you defined a target region for your study?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
Type of biomass	*Are biomass type(s) in the selected region known/available?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
Biomass properties	*Are biomass properties (e.g. moisture, ash, energy, etc.) known?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				

Stage	Step	Sector	Selected Feedstock*	Yes / No	Level of difficulty**	Comments
Seasonality	*Have seasonality and availability been identified?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
Logistics	*Are logistics and storage capacities assessed?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
Regulatory framework	*Are legal and regulatory conditions reviewed?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
Reliable data	*Is reliable data available for feedstocks?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
MFA	*Can MFA be conducted? Is further detail needed on inputs/outputs?*	Fishery				
		Urban & industrial environment				
		Agricultural				
		Forestry				
I/O Table	*Can an extended I/O table be developed?*	Fishery				
		Urban & industrial environment				
		Agricultural				

Stage	Step	Sector	Selected Feedstock*	Yes / No	Level of difficulty**	Comments
		Forestry				

6.1.2 Review of results and recommendations

6.1.2.1 Country Comparisons

The comparative analysis revealed significant variability among the six countries in terms of replication feasibility.

Spain: Spain demonstrated moderate replicability, supported by national datasets, though regional disaggregation was often necessary. Agricultural and forestry residues were relatively easy to assess, while fisheries presented data gaps. OFMSW data were available in aggregated form, requiring communication with authorities for site-specific details. Overall, replication was of moderate difficulty, mainly due to variability in feedstock-specific data completeness.

Italy: Italy demonstrated strong institutional and regulatory frameworks (e.g., Legislative Decree 152/2006, EER coding system) and comprehensive waste reporting systems. All steps were completed, but data accessibility remains a major barrier, as detailed analytical and logistics data are restricted to authorised operators. While MFA was feasible with moderate effort, I/O table development scored lowest, requiring extensive assumptions and confidential company data. The need for stakeholder engagement was significant in most sectors. Overall difficulty was moderate to high, reflecting uneven data accessibility across sectors.

Greece: Replication in Greece was among the most challenging due to fragmented and incomplete datasets for most feedstocks. Forestry sector statistics are largely unavailable, and the industry is dominated by a few major players, limiting transparency. Fisheries data are also limited, while sewage sludge information is accessible through Eurostat and ELSTAT, requiring also extensive stakeholder communication with WWTP operators. Overall, replication of tools such as MFA and I/O Tables development were possible but with high difficulty due to heavy reliance on estimates and literature-based values.

Sweden: Sweden experienced the highest overall replication difficulty. The fisheries sector was non-existent in the target region, eliminating algae as a feedstock option.

Forestry residues (GROT) are available but presented significant logistical challenges. Forestry supply chains have diminished due to declining demand, making logistics practically non-existent, although they could be re-established if market conditions change. MFA for agriculture and forestry was only possible using theoretical calculations and assumptions, and the I/O table development required additional allocation between primary and secondary products. The OFMSW was somewhat better structured but data fragmentation complicated replication, further increasing complexity.

United Kingdom: The UK showed strong replicability supported by robust national statistics. Agricultural and forestry residues were assessed with low to moderate difficulty, though the definition of their properties (e.g., moisture content, residue fate, local-level flows) required additional effort. Overall, replication was low to moderate difficulty, with challenges primarily related to level of detail rather than availability.

Germany: Germany demonstrates a well-established regulatory framework and comprehensive statistical databases, which provide structured data on agricultural and forestry residues. This regulatory clarity and data availability position Germany as an advanced context for biomass mapping. However, practical replication faces notable challenges. For agricultural residues such as wheat straw, information about logistics is highly fragmented. In the forestry sector, sawdust is a widely available by-product, and its flows are well-documented through wood resource balances. While MFA and extended I/O Tables are theoretically possible, they cannot be fully detailed due to gaps in detailed logistical and process-level data.

6.1.2.2 Sector-Specific Insights

Replication feasibility varied significantly across feedstocks, reflecting differences in market structure, data availability, and technical complexity.

Fishery: Replication for fisheries was highly constrained. Even in countries that are top producers in aquaculture, such as Spain, Greece, and Italy, only generalised or literature-based data were available, often outdated or aggregated, while in Sweden the fisheries sector is nearly non-existent, eliminating any possibility of replication. Besides that, no detailed operational datasets could be accessed without stakeholder cooperation, since they are not public. These limitations suggest that replication feasibility in the fishery sector is highly region-dependent, requiring sectoral significance and stakeholder engagement for data access.

Urban & industrial environment: Sewage sludge offered partial replicability. In Greece for example, Eurostat and national sources provided aggregated indicators, but detailed WWTP-level data were inaccessible without direct communication. This feedstock demonstrated the highest dependency on stakeholder engagement for data acquisition. On the other hand, OFMSW emerged as a feedstock suitable for replication, supported by regulation and monitoring systems. However, challenges persist due to logistics fragmentation and proprietary datasets that represent key replication barriers.

Agricultural: Agricultural feedstocks such as wheat straw demonstrated high replication potential. In almost all countries national well-documented datasets, and prior experience with biomass flows facilitated MFA and I/O development, although allocation challenges were consistent across countries. Similarly, assumptions were required on collection rates and residue distribution. Some of the replication barriers identified were logistical complexity and cost assumptions for collection and storage.

Forestry: The forestry sector displayed sharp contrasts among regions. In particular, forestry residues are well-regulated and documented in northern and central Europe (Germany, UK, Sweden), but practical replication is constrained mainly by the lack of logistics transparency and detailed chain-level data. Although forestry sector data might be available through national inventories, regional disaggregation and extended I/O modelling require assumptions, making replication challenging.

Overall, some sectors and their related bio-based feedstocks appeared to be more readily replicable than others. Well-documented feedstocks exhibited full methodological transferability across all countries, whereas less common or region-specific feedstocks required localised adaptations. This emphasises that replication success is influenced both by the nature of the feedstock and the availability of regional data.

6.1.2.3 Challenges and Limitations

Several systemic and operational challenges emerged during the replication process, often requiring adaptation of the standard methodology to ensure analytical consistency and regional relevance. A primary obstacle was data availability and quality. While some countries like the UK offered data-rich environments, even there, refining MFA necessitated local-level assumptions, introducing uncertainty. In other contexts, such as Greece and Spain, incomplete or highly aggregated datasets, particularly in forestry and fisheries, limited the robustness of analysis. Regulatory variations also played a significant role; for instance, Germany’s well-established forestry governance introduced additional compliance requirements, whereas other countries lacked enforceable frameworks, undermining data reliability. High reliance on assumptions was another cross-cutting issue, especially regarding allocation between co-products, and the estimation of residue fate. Additionally, sectoral irrelevance posed limitations. Certain feedstocks like fisheries in northern Sweden had minimal economic significance, making replication impractical. Finally, addressing data gaps often required intensive stakeholder engagement, contributing to a high communication burden.

6.1.2.4 Key Lessons and Recommendations

The replication process provided valuable insights for replication of BioReCer tools across Europe, highlighting the need for greater methodological and institutional coordination. A key recommendation is the development of standardised data templates at the EU level for MFA and data collection, with clear guidance on assumptions, allocations, and adjustments to improve consistency. Enhancing data integration is equally important, including expanding Eurostat's coverage of bioeconomy sectors and harmonizing national datasets to address fragmentation. For data-poor sectors like fisheries, the creation of sector-specific protocols, such as standardised estimation methods and minimum reporting requirements, would significantly improve data reliability. Strengthening stakeholder engagement through formal collaboration with industry actors, such as WWTP operators and forestry associations, is essential for accessing detailed, context-specific information. At the same time, maintaining methodological flexibility is crucial to accommodate regional differences in regulation, market dynamics, and logistical constraints while preserving analytical comparability. Finally, continuous monitoring of emerging challenges, including sectoral trends, will help ensure the tools remain relevant and adaptive.

6.2 BioReCer in an international value chain

As the bioeconomy continues to expand beyond regional or national borders, the integration of sustainability, traceability, and certification practices across international value chains becomes increasingly important. The BioReCer Sustainability and Circularity Assessment Framework provides a structured approach to fostering trust and transparency within the bio-based sector. However, to ensure its effectiveness on a global scale, it is essential to examine its relevance and adaptability to different regulatory systems and market conditions. To explore this, a dedicated case study was conducted to evaluate the applicability of the BioReCer Sustainability and Circularity Assessment

Framework in non-European value chains and market environments, engaging stakeholders operating outside the EU.

6.2.1 Semi-structured interviews

This section outlines the methodology used to conduct interviews aimed at exploring the suitability and implementation potential of the BioReCer Sustainability and Circularity Assessment Framework in bio-based value chains outside Europe.

6.2.1.1 Interview methodology

The approach used to assess replicability and transferability of the BioReCer Sustainability and Circularity Assessment Framework in international value chains was based on a structured methodology comprising the following components:

- Sampling methodology
- Definition of target participant groups
- Step-by-step procedural framework
- Overview of the interview questionnaire

6.2.1.1.1 Sampling methodology

The analysis of relevance and applicability of the BioReCer Sustainability and Circularity Assessment Framework in non-European value chains was conducted through a semi-structured, in-depth qualitative interview study. A carefully designed sampling strategy was applied to ensure representation across relevant stakeholder groups. Interview participants were drawn from diverse sectors, and geographical regions. These individuals were selected by project partners based on their relevance and potential impact on the project's expected outcomes.

6.2.1.1.2 Target groups

The target groups for the BioReCer interviews within the international replicability case study were selected to represent stakeholders mainly outside Europe – or based in Europe but involved in an international value chain - that are potential users of the BioReCer Sustainability and Circularity Assessment Framework. More specifically, the following groups were targeted:

- companies that produce, use, or are willing to use biological feedstocks, including residual biomass and organic waste, for the development of bio-based products, excluding those in the food, feed, and bio-energy sectors.
- companies engaged in international trade, either as importers or exporters of biological feedstocks, intermediate bio-based materials, or final bio-based products.

The inclusion of companies operating in international contexts was essential to evaluate the potential for broader adoption and replication of the BioReCer Sustainability and Circularity Assessment Framework, and to identify barriers, drivers, and opportunities related to bio-based production and sustainability assessment that are beyond regional levels.

Overall, three interviews were conducted with companies operating in the following sectors: water and sanitation, packaging, biomaterials and wooden construction, bioplastics, and bioethanol.

6.2.1.1.3 Procedure followed

The process followed a structured approach consisting of three main phases:

1. **Phase I: Identification and Recruitment of Participants**
   During the initial phase, potential interviewees were identified from project partners' networks, focusing on companies representing the predefined stakeholder groups. Subsequently, the selected individuals were invited to take part in an online interview. Each invited participant received an "Information Sheet" and an "Informed Consent Form" outlining the purpose and terms of the interview. Participation proceeded only after the signed consent form was returned. To support transparency and preparation, the interview questionnaire, as well as an overview of the BioReCer Sustainability and Circularity Assessment Framework were shared with participants in advance.

2. **Phase II: Conducting the Interviews**
   This phase involved the actual implementation of the interviews, which were conducted through digital means. Each interview lasted approximately 30 minutes and was guided by the structured questionnaire, tailored to the specific sector of the interviewee.

3. **Phase III: Reporting and Data Consolidation**
   In the final phase, the main findings of each interview were collected for further analysis, contributing to the overall evaluation and integration of international stakeholder insights on the BioReCer Sustainability and Circularity Assessment Framework.

Throughout the entire process, strict attention was paid to ensuring participant privacy, in full accordance with the principles outlined in the General Data Protection Regulation (GDPR).

6.2.1.1.4 Interview questionnaire overview

An interview questionnaire was developed to address the specific perspectives and roles of the targeted stakeholder group. The full list of questions, along with the corresponding Information Sheet and Informed Consent Form provided to participants, can be found in Annex A.

The questionnaire aimed to further investigate stakeholders' views on sustainability certification schemes for biological feedstocks and bio-based products, in order to better align the project's results and offerings with their needs. In particular, the goal of this set of questions was to identify how the international bio-based value chains are certified, and mostly whether the BioReCer Sustainability and Circularity Assessment Framework and its proposed indicators could be applied. This would contribute to shedding light on the main challenges faced by relevant stakeholders during their adoption and implementation. Finally, individuals representing bio-based industries elaborated on their perceptions around the BioReCer Sustainability and Circularity Assessment Framework, their willingness to use this framework as well as on the cases they would consider using such a system.

6.2.2 Analysis of interviews

This section analyses the data collected from the interviews and highlights the main insights derived from the interviewees' expertise and experiences of sustainability certification schemes in bio-based value chains. Based on the scope of the questionnaire, the following overarching themes were addressed:

1. Type of biological feedstocks used, and bio-based products developed
2. Experience with Sustainability Certification Schemes applied
3. Applicability of the BioReCer Sustainability and Circularity Assessment Framework
4. Desired improvements and future expectations

As previously mentioned, the interviewees came from diverse backgrounds and sectors. Each of the companies interviewed is considered a significant player in its respective field, with a long-established presence. The organizations are not only based in Europe but also operate internationally, including in regions such as Brazil. The following sub-sections present the main findings corresponding to each of the above-mentioned themes.

6.2.2.1 Type of biological feedstocks used, and bio-based products developed

The interviews confirm that biomass serves as the central input for various bio-based products' development across all companies. However, the extent and type of biomass use varies. Only a limited number of companies rely their core activities on available residual biomass, whereas most of them employ local secondary biomass mainly within use case projects. Despite operating in different regions, none of the companies reported engaging in biomass trading, mainly due to regulatory classifications that categorise residual biomass as waste, complicating its utilization and commercialisation.

Moreover, supply chain complexity emerged as a recurring theme, particularly at the production and farm level where numerous small suppliers and intermediaries are involved. This fragmentation, combined with logistical issues such as transporting certified and non-certified material together, creates significant challenges for maintaining traceability. Customers increasingly demand assurance of certified product origin, highlighting the need for more robust verification and monitoring systems across bio-based value chains. A further insight concerns the valorisation of by-products. For example, while some materials have traditionally been returned to agricultural systems as fertilisers, companies are now exploring additional pathways such as biogas production or the development of commercial products. These strategies hold potential for improving resource efficiency and creating new revenue streams. Nevertheless, the economic feasibility remains uncertain, as processing costs often exceed the market value of the resulting products.

Overall, the analysis indicates that while companies have already been using biomass, three critical challenges persist:

1. expanding the effective use of residual biomass,
2. strengthening traceability mechanisms in complex supply chains, and
3. developing cost-effective solutions for by-product valorisation.

Addressing these issues will be central to improving the sustainability and scalability of bio-based value chains.

6.2.2.2 Experience with Sustainability Certification Schemes applied

The interviews revealed diverse experiences with sustainability certification, ranging from reliance on established third-party schemes to the development of internal frameworks inspired by recognised international standards. In some cases, companies have designed their own assessment systems, to foster continuous improvement and ensure closer engagement with the involved value chain actors. These internal systems often cover social indicators, including labour rights, wages, health and safety, while also placing responsibility on companies for their suppliers' compliance. This approach allows for flexibility and proximity in procurement control, and in some instances is perceived as more effective than relying solely on external certification.

A key theme that emerged is the regional variation in regulatory and market drivers for certification. In the European context, sustainability requirements are strongly influenced by legislation and customer demand. For example, while regulations for biofuels are highly prescriptive, with mandatory sustainability criteria (e.g., RED compliance), bioplastics currently fall under a voluntary framework, leaving customers to drive higher expectations than legislation requires. Interviewees highlighted that European market actors frequently enforce requirements that go beyond legal regulations, effectively raising the standards for companies operating in this market. Some suggested that the EU could consider incorporating an approach that also measures the extent to which bio-based materials replace fossil-based alternatives.

Outside of Europe, regulatory environments present both opportunities and barriers for certification. For example, in some regions, regulations governing production of bio-based products such as fertiliser (e.g., standards set by ministries of agriculture) specify parameters such as heavy metal thresholds. While these rules are generally manageable for companies with consolidated operations, a persistent challenge lies in the classification of residual biomass like sewage sludge and similar residues as waste rather than by-products. This classification complicates the development of new products that use residual biomass as raw material, particularly in areas where state-level regulations impose additional restrictions. The inability to monitor the final disposal further complicates compliance, highlighting a gap between waste legislation and circular economy ambitions. A potential solution identified by interviewees would be to establish administrative procedures that treat such materials as raw materials or products rather than waste, thereby enabling clearer monitoring and more effective market integration.

Finally, interviewees noted that the ease of certification processes often depends on the certification body and the flexibility of each certification scheme. Standardised processes were generally perceived as manageable, though requirements and interpretations can vary between schemes, creating uneven experiences across different markets and product categories.

In summary, experiences with sustainability certification schemes reflect a spectrum of approaches: from voluntary customer-driven standards and internal frameworks to mandatory compliance with regional legislation. The analysis indicates that:

1. Organizations frequently supplement or replace third-party certification with

internal frameworks tailored to their supply chains, enabling closer oversight and continuous improvement.

2. Compliance with sustainability standards is generally achievable, especially for consolidated operations, but specific regulatory classifications (e.g., sludge as waste) can introduce operational and administrative challenges.
3. Voluntary schemes can play a vital role where legislation is absent or less prescriptive.
4. European legislation drives strict requirements, customer expectations often exceed legal standards, highlighting the importance of robust internal frameworks.
5. The credibility and effectiveness of certification depend not only on the standards themselves but also on how they are implemented and monitored by certification bodies.

6.2.2.3 Applicability of the BioReCer Sustainability and Circularity Assessment Framework

Interviewees generally expressed a positive attitude towards the potential adoption of the BioReCer Sustainability and Circularity Assessment Framework , viewing it as a useful tool to strengthen circularity monitoring and improve market credibility. Companies positioned as intermediate producers noted that certain sustainability aspects, such as biodiversity protection, lie primarily with upstream actors (e.g., primary producers). For them, the BioReCer requirements would serve as a structured means to ensure supplier compliance through documentation, verification, and traceability measures.

Two main benefits were highlighted. First, the BioReCer Sustainability and Circularity Assessment Framework provides clear guidance on the type of information suppliers should deliver, which could facilitate more systematic and effective audits. Second, adoption of the BioReCer Sustainability and Circularity Assessment Framework could enhance the market value of certified products, particularly in regions where clients place strong emphasis on traceability and compliance with directives such as the EU Deforestation Regulation (EUDR). The geographic origin of biomass was underlined as a critical parameter, alongside social sustainability aspects, especially in contexts where local legislation offers limited protection to vulnerable groups, such as seasonal workers in developing countries. Moreover, interviewees stressed that certification should go beyond minimum regulatory requirements to address such gaps.

Another important dimension relates to circularity. Companies already use internal circularity KPIs and seek to align their operations with cascading use principles, aiming to maximise the production of valuable products before resorting to energy recovery. Standards such as ISO 59000 on circularity and the consideration of biogenic carbon flows were identified as relevant reference points. In this sense, the BioReCer Sustainability and Circularity Assessment Framework was perceived as complementary, offering additional methodological support and benchmarks that could be integrated into existing assessment frameworks. The BioReCer Sustainability and Circularity Assessment Framework was also valued for its practicality. Interviewees reported that the provided documentation offered clear and useful guidance, reducing the need to start from scratch when implementing new requirements. In particular, it was noted that having a structured methodology enables companies to critically assess whether practices such as using sewage sludge as fertiliser are environmentally and socially sound.

Overall, the analysis suggests that the BioReCer Sustainability and Circularity Assessment Framework holds significant potential to:

1. Strengthen traceability and monitoring across complex bio-based supply chains.
2. Provide market-relevant credibility by addressing key parameters such as social conditions.
3. Complement existing sustainability certification frameworks with structured guidance and benchmarks, particularly in relation to circularity and cascading use.

These insights indicate that companies view the BioReCer Sustainability and Circularity Assessment Framework not as a replacement but as an enrichment of their current systems, with potential to improve both operational practices and market positioning.

6.2.2.4 Desired improvements and future expectations

Interviewees identified several areas where the BioReCer Sustainability and Circularity Assessment Framework could be improved to better support implementation and increase its value for industry and markets. A key concern relates to harmonisation and simplification, as suppliers are already required to comply with multiple certification schemes and legislative frameworks. Without streamlining, the additional administrative burden risks undermining uptake. Interviewees suggested that alignment with established instruments such as the EU Ecolabel would strengthen the framework's relevance while reducing duplication. Beyond simplification, interviewees emphasised the need for the framework to capture the dynamic nature of the circular economy. Current criteria primarily reflect the status quo, but circularity is an evolving process that requires continuous innovation. To address this, interviewees recommended adding forward-looking indicators.

Another proposal was to introduce a quantitative scoring system (e.g., A–C ratings) alongside the existing qualitative framework. This would enable comparability between companies, facilitate benchmarking, and provide clearer signals to markets and stakeholders. A scoring approach was seen as a way to build transparency and encourage collective progress within the bio-based sector. Interviewees also highlighted the importance of developing more sophisticated indicators for circularity and renewability. Current reporting often focuses on basic measures, such as technical recyclability, or relies on vague definitions, such as "sustainable source" for renewability. However, these measures fail to adequately capture the complexity of circular systems and chains of custody. There is therefore a pressing need for clearer, standardised, and operational definitions and indicators that reflect advanced aspects of circularity, such as cascading use, biogenic carbon flows, and intelligent reuse strategies.

Finally, participants stressed the importance of broad dissemination of the framework once finalised. Suggestions included leveraging networks such as the International Water Association (IWA), the Joint Research Centre (JRC) and forming consortia to ensure knowledge exchange and uptake across industries.

In summary, interviewees' expectations point toward four major upgrades for the BioReCer Sustainability and Circularity Assessment Framework:

1. Greater **harmonisation with existing labels and legislation** to reduce administrative complexity.
2. Inclusion of **forward-looking criteria** to reflect the dynamic and innovative nature of the circular economy.
3. Introduction of **quantitative scoring system** to enable benchmarking and comparability.
4. Development of clearer and more advanced indicators for circularity and renewability, supported by **wide dissemination through international networks**.

These improvements would not only enhance the usability of the BioReCer Sustainability and Circularity Assessment Framework but also increase its credibility and impact in supporting sustainable and circular bio-based value chains.

6.2.3 Consolidated findings

The findings from this semi-structured, in-depth qualitative study provide valuable input that will inform several key dimensions of the BioReCer project. These insights include:

1. **Biomass use and valorisation**: need to expand effective use of residual biomass (despite their classification as waste) and develop cost-efficient valorisation pathways.
2. **Traceability and supply chains**: the importance of strengthening verification and monitoring mechanisms in fragmented and complex value chains.
3. **Certification practices**: the role of harmonising schemes, overcoming regulatory barriers, and ensuring credibility through consistent implementation.
4. **Applicability of the BioReCer Sustainability and Circularity Assessment Framework**: its value as a complementary tool to existing systems, enhancing traceability, circularity, and social accountability.
5. **Future expectations**: the demand for harmonisation, forward-looking indicators, benchmarking tools, and advanced circularity metrics, supported by wide dissemination.

Overall, the BioReCer Sustainability and Circularity Assessment Framework is seen as a practical and complementary instrument that can:

1. Improve utilisation of residual biomass.
2. Strengthen sustainability and traceability across fragmented supply chains.
3. Enhance certification credibility and market value.
4. Provide forward-looking guidance to support circular bio-based systems.

7 Conclusions

Transferability and replicability are crucial aspects when scaling up innovative solutions, but they often involve more than simply copying a model from one context to another. While transferability might seem straightforward, experience shows that successful replication requires significant effort from those demonstrating the solutions to those adapting them to new local needs. The work presented in this Deliverable demonstrates that replicating and transferring the BioReCer outcomes to other regions and value chains is feasible, but not without challenges. This process underscores the importance of careful adaptation to local conditions, stakeholder engagement, and alignment with regulatory, social, and economic contexts.

The BioReCer transferability and replicability approach provides a structured strategy to ensure that bio-based certified systems add value to biological feedstocks and their supply chains. It encompasses five complementary steps that collectively guide the selection, adaptation, and implementation of proven solutions, balancing technical fidelity with necessary context-specific adaptations:

1. assessment of local needs and building stakeholder communities,
2. mapping of biological feedstock flows,
3. selection and calculation of relevant sustainability and circularity indicators,
4. integration with existing certification schemes, and
5. deploying of ICT tools.

BioReCer solutions have demonstrated tangible value in:

- Expanding the efficient use of residual biomass and creating cost-effective valorisation pathways.
- Strengthening verification, traceability, and trustworthiness across complex supply chains.
- Enhancing certification credibility and ensuring consistency across markets.
- Supporting circularity, cascading use of resources, and continuous innovation.

These outcomes are underpinned by a suite of tools and resources, including the BioReCer Sustainability and Circularity Assessment Framework, the BRIE Living Lab, the BIT with its Decision Support System, the Practica guidance document for the certification schemes, the Biological Feedstock Label, the EIP, and the Standardization Toolkit and Roadmap. Collectively, these enablers provide practical guidance for implementation, monitoring, and knowledge sharing, supporting both short-term adoption in European regions and long-term global transferability.

Extensive demo case studies have further validated the replicability and transferability of BioReCer outcomes. Replication exercises across six European countries (Greece, Spain, Italy, Sweden, the UK, and Germany) highlighted that for well-documented feedstocks, such as agricultural residues, BioReCer outcomes are highly transferable, whereas for others, including fisheries, require significant stakeholder engagement and contextual adaptations. These exercises emphasised the importance of standardised data collection, methodological flexibility, and coordination with regional regulations for reliable assessment of sustainability and circularity. At international level, semi-structured interviews with companies in diverse bio-based sectors confirmed the BioReCer sustainability framework's potential as a complementary tool to existing sustainability certifications. Stakeholders valued its ability to strengthen traceability, circularity monitoring, and market credibility. They also identified opportunities for improvement, including alignment with existing schemes, introduction of forward-looking circularity indicators, development of quantitative benchmarking tools, and wider dissemination through international networks.

In conclusion, by following the presented stepwise methodology, BioReCer ensures that solutions are both context-specific and scalable. This iterative process strengthens local engagement and capacity building, provides a robust framework for monitoring and optimizing bio-based processes, and offers a practical roadmap for replicating sustainable and circular bio-based initiatives. Challenges remain, including alignment with existing certification schemes, reducing administrative burdens, and integrating advanced sustainability indicators. Addressing these challenges is essential for tools to be credible, practical, and capable of supporting industry innovation while bridging regulatory gaps. Overall, BioReCer provides a scalable, complementary framework along with a suite of tools for promoting sustainability and circularity in bio-based systems. Its structured transferability and replicability approach, combined with supporting digital and stakeholder tools, positions the project to facilitate broader adoption of sustainable practices, reinforcing the EU's vision for a resilient, competitive, and circular bioeconomy.

List of abbreviations

BIT	BioReCer ICT Tool
BRIE-LL	BioResources Innovation Ecosystem Living Lab
BRSP	BioResources Stakeholders Platform
CBs	Certification Bodies
CE	Circular Economy
Dx.x	Deliverable x.x
DM	dry mass
EER	European Waste Catalogue / EER coding system
EIP	Electronic Identification Passport
EU	European Union
EUDR	EU Deforestation Regulation
FSC	Forest Stewardship Council
GDPR	General Data Protection Regulation
GROT	Grenar och toppar (Tops and branches in Swedish)
I/O Table	Input/Output Table
ICT	Information and Communication Technology
ISCC	International Sustainability and Carbon Certification
ISO	International Organization for Standardization
MC	moisture content
MFA	Material Flow Analysis
OFMSW	Organic Fraction of Municipal Solid Waste
RED	Renewable Energy Directive
T&T framework	Track and Traceability framework
UK	United Kingdom
WM	wet mass
WP	Work Package
WWTP	Wastewater Treatment Plant

References

Brunner, P. H., & Rechberger, H. (2004). Practical handbook of material flow analysis. *The International Journal of Life Cycle Assessment*, *9*, 337–338. https://doi.org/10.1007/BF02979426

Brunner, P. H., & Rechberger, H. (2016). *Handbook of Material Flow Analysis: For Environmental, Resource, and Waste Engineers* (2nd ed.). CRC Press.

Choi, H. H., Hwang, Y. W., Kim, J., Kang, H. Y., & Kim, D. H. (2024). Material flow and domestic demand analysis for nickel in South Korea. *Journal of Cleaner Production*, *449*, 141711. https://doi.org/https://doi.org/10.1016/j.jclepro.2024.141711

Hendriks, C., Obernosterer, R., Müller, D., Kytzia, S., Baccini, P., & Brunner, P. H. (2000a). Local Environment The International Journal of Justice and Sustainability Material Flow Analysis: A tool to support environmental policy decision making. Case-studies on the city of Vienna and the Swiss lowlands) Material Flow Analysis: A tool to support environmental policy decision making. Case-studies on the city of Vienna and the Swiss. *Lowlands, Local Environment*, *5*, 311–328. https://doi.org/10.1080/13549830050134257

Hendriks, C., Obernosterer, R., Müller, D., Kytzia, S., Baccini, P., & Brunner, P. H. (2000b). Local Environment The International Journal of Justice and Sustainability Material Flow Analysis: A Tool to Support Environmental Policy Decision Making. Case-Studies on the City of Vienna and the Swiss Lowlands) Material Flow Analysis: A Tool to Support Environmental Policy Decision Making. Case-Studies on the City of Vienna and the Swiss. Lowl. *Local Environ.*, *5*, 311–328. https://doi.org/10.1080/13549830050134257

Huang, C.-L., Vause, J., Ma, H.-W., & Yu, . C.-P. (2012). *Using material/substance flow analysis to support sustainable development assessment: A literature review and outlook. Resources, Conservation and Recycling, 68, 104–116*. https://doi.org/https://doi.org/10.1016/j.resconrec.2012.08.012

Kalt, G. (2015a). Biomass Streams in Austria: Drawing a Complete Picture of Biogenic Material Flows within the National Economy. *Resour. Conserv. Recycl.*, *95*, 100–111. https://doi.org/10.1016/J.RESCONREC.2014.12.006

Kalt, G. (2015b). Biomass streams in Austria: Drawing a complete picture of biogenic material flows within the national economy. *Resources, Conservation and Recycling*, *95*, 100–111. https://doi.org/10.1016/J.RESCONREC.2014.12.006

Marques, A., Cunha, J., De Meyer, A., & Navare, K. (2020). Contribution Towards a Comprehensive Methodology for Wood-Based Biomass Material Flow Analysis in a Circular Economy Setting. *Forests 2020, Vol. 11, Page 106*, *11*(1), 106. https://doi.org/10.3390/F11010106

Ning, J., Tang, S., Fu, Y., Liu, G., Sun, Y., Feng, Z., Huang, D., & Shi, L. (2025). Substance flow analysis of polyethylene terephthalate (PET) fiber in China.

Resources, Conservation and Recycling, 212. *107984. Https*. https://doi.org/https://doi.org/10.1016/j.resconrec.2024.107984

OECD. (2008). *Measuring Material Flows and Resource Productivity. Volume I. The OECD Guide*. OECD Publishing. https://www.oecd.org/environment/indicators-modelling-outlooks/MFA-Guide.pdf

Raj, R. S., Jain, S., & Kumar Sharma, A. (2024). Transforming municipal solid waste management through material and substance flow analysis: Conversion pathways for sustainable energy production. *Energy Conversion and Management*, *322*, 119164. https://doi.org/https://doi.org/10.1016/j.enconman.2024.119164

Annex A: Interviews questionnaires, Information Sheet and Informed Consent Form

A.1: Interview Questionnaire

Introduction

We would like to invite you to take part in an interview that is being carried out by BioReCer, a 3-year project funded by the European Union within the framework of the Horizon Europe programme.

What is the BioReCer project all about?

BioReCer aims to ensure the environmental performance and traceability of the biological feedstocks used by the bio-based industries (**excluding food, feed and bioenergy sectors**), deploying guidelines to strengthen the current certification schemes. Within this approach, added-value, the use, as well as social acceptance of bioproducts will be increased. To fulfil this goal, BioReCer is structured in three main technological pillars focusing on:

1. developing a multidimensional assessment framework for an aggregated analysis on the biological feedstocks and their associated supply chains.
2. creating a BioReCer Innovation ecosystem living-lab with a multi-agent approach, testing the framework in 4 bio-based supply chain case studies, and
3. using all this knowledge to complement current certification schemes including new criteria for certifying biological resources' sustainability, origin, and traceability, and ensure applicability at EU and global scale.

Key definitions

To ensure that all participants have a common understanding of the terminology used, some key definitions are provided below. We invite you to read these definitions before answering the interview's questions.

- **Bio-based**: according to the official European standard, means "derived from biomass"*.* The term bio-based is mainly used to describe products whose carbon atoms originate from biogenic instead of fossil sources. These products can be made entirely or partially from biomass such as plants, trees, marine organisms or animals and can be subject to physical, chemical or biological processes. In BioReCer, the considered and valorised feedstock for bio-based products is biogenic wastes and residues from agriculture, fishery, forestry and municipality (OFMSW).
- **Biomass**: Biomass describes biogenic matter that is available on a renewable basis, including agricultural crops and trees, wood and wood waste and residues, plants (including aquatic plants), microorganisms, fungi, grasses, residues, fibres, animal wastes, organic municipal wastes and other waste materials. Biomass encompasses any biogenic material to be used as raw material. The biomass assessed in BioReCer comes from agriculture, fishery, forestry and municipalities.
- **By-product**: Secondary product derived from a production process, manufacturing process or chemical reaction; it is not the primary product or service being produced. A by-product is defined as a production residue that is not a waste.

- **Feedstock**: A feedstock is the unprocessed raw material of a manufacturing process. In general, any natural material can be viewed as a feedstock. These include minerals or materials from vegetation or water, including crops, wood, algae and organic matter, but also fossil resources like petroleum, coal and natural gas. Therefore, the term "feedstock" is often used as a synonym for raw material.
- **Label and Certification Schemes:** Label and certification schemes are structured frameworks that communicate product quality and compliance with specific standards to both businesses and consumers. They inform about the quality, safety and environmental impact of products. Certification schemes involve third-party verification that a product or service meets defined standards. This process typically includes audits and assessments to ensure compliance. Label and certification schemes play crucial roles at both B2B (business-to-business) and B2C (business-to-consumer) levels by promoting transparency, ensuring compliance with standards and building consumer trust.
- **Residue**: according to the European Commission, residues are materials that are not deliberately created in a production process. They can be classified as either waste or by-products, depending on their characteristics and intended use.
- **Secondary Raw Material**: Recycled material substances that meet end-of-waste criteria as defined in the European Directive 2008/98/EC on waste.

Questionnaire

This questionnaire is addressed to companies that produce, use or are willing to use biological feedstocks, including residual biomass and waste, for bio-based products <u>**excluding food, feed and bioenergy sectors,**</u> **and** are involved in **international trade** as part of their value chain. This includes companies that import or export biological feedstocks, intermediate materials, or final bio-based products. The questions to be posed are the following:

Company website: ....

Interviewee email address: ....

Respondent Details

Name?

Job title?

Background?

Brief description of your current role and responsibilities?

Corporate Entity Details

- Name?
- Date established?
- Sector of operation?
- Headquarter location? How many other sites? Where are the other sites located?
- Brief description of the entity's core activities

Q1: What type of biological feedstocks or bio-based products does your business use in the production process or produce (please refer to the main two or three biological feedstocks or biobased products in case of multiple feedstocks/products)? *What stage are you currently in, was the product recently newly introduced, what type of biomass do you use?*

Q2: Which sustainability certification standards are you using for your company? *(For example: ISO 9001, ISO 14001, ISO 45001, ISCC, ISCC PLUS etc.).*

Q3: Do you find it generally hard to get certified? Why?

Q4: When it comes to sustainability certification schemes for bio-based value chains, have you ever gone through a relevant process before? If yes, what kind of data was required? What was good in the process? What should be different? If not, why?

Q5: Have you been asked to comply with specific European environmental legislation to trade in the EU? Do you think it would be easier if you were certified with a specific sustainability certification scheme for bio-based value chains, recognised by the EC?

Q6: The BioReCer framework represents a significant advancement in integrating sustainability and circularity principles into certification schemes for biological resources. Do you believe it could benefit you? How? *(For example: More Customers, Earning Potential, Enhanced Brand Image and Reputation, Market Access/Increased Exports, Regulatory Compliance, Supply Chain Optimization, Improved Processes, Build Employee Pride, other?)*

Q7: Going through the BioReCer certification framework, which indicators are you mainly interested in? *How would you rate the certification process concerning its workload? Would it be feasible for you to collect and provide all the required information and data? Did you identify any issues during the BioReCer certification process?*

Q8: Overall, what is your opinion on the resulting certification? *Do you have any suggestions for improvements/amendments when employed to an international/your bio-based value chain/case study?*

A.2: Information Sheet

Introduction

We would like to invite you to take part in an interview that is being carried out by BioReCer, a 3-year project funded by the European Union within the framework of the Horizon Europe programme. In the following lines you will find all the necessary information on why this interview is being conducted and what will it involve for you to help you in your decision to participate. Please take the time to read this information sheet carefully and ask questions about anything you do not understand.

What is the BioReCer project all about?

BioReCer aims to ensure the environmental performance and traceability of the biological feedstocks used by the bio-based industries (**excluding food, feed and bioenergy sectors**), deploying guidelines to strengthen the current certification schemes. Within this approach, added-value, the use, as well as social acceptance of bioproducts will be increased. To fulfil this goal, BioReCer is structured in three main technological pillars focusing on:

4. developing a multidimensional assessment framework for an aggregated analysis on the biological feedstocks and their associated supply chains.
5. creating a BioReCer Innovation ecosystem living-lab with a multi-agent approach, testing the framework in 4 bio-based supply chain case studies, and
6. using all this knowledge to complement current certification schemes including new criteria for certifying biological resources' sustainability, origin, and traceability, and ensure applicability at EU and global scale.

The BioReCer project brings together a consortium of 17 partners across 7 different European countries. The partners of the project are presented at the end of the present Information Sheet.

Why have I been invited to take part in this interview?

You have been invited to take part in this interview because you have been identified as a key international stakeholder for BioReCer. In this context, we would like to learn more about your views on sustainability certification schemes for biological feedstocks and bio-based products, so as to better shape the project's outcomes and its offers to your needs.

Is my participation voluntary?

Your participation is entirely voluntary. There will be no adverse consequences if you decide not to participate or withdraw at a later stage. In fact, you may withdraw your participation at any time, as well as request for your data to be withdrawn without giving a reason and without prejudice. If you withdraw from the survey, any identifiable data already collected will be retained if you allow us to. Anonymous data already collected will be used because we cannot trace the information back to you. No further data would be collected, or any other procedure would be carried out in relation to you.

What will my involvement in this survey require?

If you agree to take part in this survey by being interviewed, we will ask you to sign an Informed Consent Form and you will be given this Information Sheet to keep along with a copy of your signed Informed Consent Form. The project ends in August 2026, but your involvement would only be for as long as you wish. During this time, you may be asked to participate, if you wish, in workshops and events held by the BioReCer project. You are free to decline to participate in any of these activities, as you wish.

How will you handle my data?

Your data will be held in complete confidence, and we will follow ethical and legal practice in relation to all interview procedures. Personal data (such as your name, contact details, etc.) will be handled in accordance with the GDPR. Your personal data will be stored securely. You will not be identified in any reports/publications resulting from this interview and those reading them will not know who has contributed to it.

Are there any risks involved?

There are no risks involved in this study.

Whom do I contact if there is a problem?

Any complaint or concern about any aspect of your experience during the interview will be addressed. If you wish to complain, or have any concerns in this respect, then you should communicate with the partner of the BioReCer consortium that is conducting the survey, using the details provided below.

BioReCer consortium partner: CERTH

Contact person: Maria Batsioula

Email: m.batsioula@certh.gr

Thank you for taking the time to read this Information Sheet!

Who are the partners participating in the BioReCer project?

- **CETAQUA**, Spain (BioReCer Coordinator) - A model of public-private collaboration that was created to ensure the sustainability and efficiency of the water cycle while taking regional needs into account. For more information visit **www.cetaqua.com**
- **Cittadinanzattiva APS - ACTIVE CITIZENSHIP NETWORK**, Italia – an Italian organisation, which promotes civic participation and the protection of citizens' rights in Italy and in Europe. Since 2001, it works also at the EU level thanks to its EU branch called "Active Citizenship Network" (ACN). More information at **www.activecitizenship.net**
- **ANFACO-CECOPESCA**, Spain - a private non-profit business association, representing and defending the sectoral interests of more than 250 companies from the marine and food industry sector. It also provides high added value services through its Technology Centre. For further information please visit **https://anfaco.es**
- **BETANIA LEGIO SL**, Spain - a Spanish SME with more than 20 years of experience in favouring the impact and exploitation of the results of R&D&I projects by establishing the necessary Go-To-Market and commercial exploitation strategies and actions. It has developed more than 1,000 technology-based products and services in the market. More information at: **http://www.betanialegio.es**
- **BRUNEL**, UK - an international university focused on providing education and research relevant to industry and society. A key focus of Brunel's research team is sustainable resource recovery from waste and wastewater, data analytics, process modelling, decision support systems, circularity and sustainability measurement and assessment, as well track and traceability assessment frameworks. More information at: **https://www.brunel.ac.uk**

- **CAP**, Italy - A publicly funded company that manages the integrated water service in the metropolitan city of Milan and various other municipalities in the provinces of Monza and Brianza, Pavia, Varese and Como according to the in-house providing model, guaranteeing the public control of the member bodies in accordance with the principles of transparency, responsibility and participation. The company is also one of the protagonists of the Water Alliance, the network of 13 companies from Lombardy. More information at: **https://www.gruppocap.it**
- **CERTH**, Greece - The largest R&D organization in Northern Greece, and Centre of Excellence in development, exploitation, and dissemination of novel technologies. In BioReCer, CERTH is represented by two Institutes: (i) the Institute of Bio-Economy and Agri-Technology (iBO | Laboratory of Environmental Engineering & Sustainability) and (ii) the Chemical Process & Energy Resources Institute (CPERI | Natural Resources and Renewable Energy Lab). More information at: **https://www.certh.gr**
- **Cluster SPRING**, Italy - a non-profit association that creates networks and value chains for Italy's bio-based industry, acting as the Italian Circular Bioeconomy Cluster. More information at: **https://www.clusterspring.it**
- **EGM**, France - An SME that creates, produces, and provides scalable and interoperable solutions to collect and exchange information connecting the physical world to the digital world in order to allow private and public actors to optimise and improve their services. EGM supports its clients thanks to its permanent innovation approach and its operational know-how of the data life cycle, from acquisition to data processing. More information at: **https://www.egm.io**
- **Meo Carbon Solutions**, Germany - an independent consulting company with a special work focus and a long working history around renewable resources, wastes and residues, renewable energies, and biofuels. MCS has a thorough understanding of upstream and downstream operations, sustainability, certification, climate change and GHG calculations. More information at: **https://www.meo-carbon.com**
- **nova-Institut GmbH**, Germany – A company working in the field of sustainability since the mid-1990s and today focuses primarily on the areas of circular economy, bioeconomy and CO2 utilisation. The independent company supports the chemical and plastics industries in the transition from fossil to renewable carbon – based on biomass, CO2 utilisation or recycling – through research and science-based consulting. Both in accompanying research for innovation projects and in individual business consulting, nova's interdisciplinary team covers the entire value chain. It works on all topics from raw materials, technology scouting and market research to economics, policy, life cycle assessments and sustainability, as well as support in communication and strategy development. More information at: **https://nova-institute.eu**
- **RISE**, Sweden - an independent research institute. The unit within RISE who is active in BioReCer, RISE Processum AB, focuses on biorefinery development and possesses a unique research environment where new ideas and products may be tested from laboratory to demo scale. We are a linkage between research and commercialization. More information at: **https://www.ri.se/en/processum**
- **UNI**, Italy - the Italian Standardisation body, a private, non-profit association to develop, approve and publish voluntary standards in all economic sectors (industry, trade and services) excluding electric and electrotechnical ones. UNI is the official Italian member of CEN (European Committee for Standardization) and ISO (International Standard organisation) as acknowledged by the EU Reg. N.

1025/2012 and the Italian law D.L 223 of 15/12/2017. More information at: **https://www.uni.com**

- **UnitelmaSapienza**, Italy - one of the most active online universities in Italy that, besides teaching activities, has a strong focus on research activities with both national and international impact. The research line of our research team (the Bioeconomy in Transition Research Group – BiT-RG) is related to sustainable transition and circular bioeconomy. More information at: **https://www.unitelmasapienza.it**
- **The University of Santiago de Compostela**, Spain - a public institution of higher education and research, composed of 28 institutes and research centers and 299 research groups. One of the research centers of excellence is CRETUS (Cross-Research in Environmental Technologies), in which BIOGROUP is integrated, a reference research group in LCA, wastewater treatment, circular economy, environmental management, among other topics. More information at: **https://www.usc.gal**
- **Università Politecnica delle Marche**, Italy - a university which was founded in 1969 in Ancona (Marche, Italy). It hosts 5 fields of education, 12 research departments and more than 50degree courses. The WWEELab (Water and Waste Environmental Engineering Lab) Research Group, coordinated by Prof. Francesco Fatone, manages several research projects funded by the main EU research programmes. More information at: **https://www.univpm.it**

A.3: Informed Consent Form

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

I confirm that I understand that by ticking/initialling each box below I am consenting to this element of the study. I understand that it will be assumed that unticked/uninitialed boxes means that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element I may be deemed ineligible for the study.

- ✓ I have read and understood the Information Sheet with which I was provided. I have been given a full explanation of the nature, purpose, location and likely duration of the interview, and of what will be expected from me in its context. ☐

- ✓ I have had an opportunity to consider what information will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction. ☐

- ✓ I understand that my personal data will be held and processed in confidence and in accordance with the principles laid out by GDPR. ☐

- ✓ I understand that my participation is voluntary and that I am free to withdraw from the study at any time without the need to justify my decision. ☐

- ✓ I confirm that I have read and understood the above and freely consent to participate in the survey. I have been given adequate time to consider my participation. ☐

- ✓ I am aware of whom I should contact if I wish to lodge a complaint ☐

If you would like your contact details to be retained so that you can be contacted in the future by the project researchers who would like to invite you to participate in further activities of this project, or in future studies of a similar nature, please tick the appropriate box below.

	Yes, I would be happy to be contacted in this way	
	No, I would not like to be contacted	

Name of interviewee:

....

Signature: ....

Date: ....

Name of person receiving consent: ....

Signature: ……………………………………………………
Date: ……………………………………………………………………………