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Publishable executive summary

This deliverable presents the main findings from the validation of the BioReCer ICT Tool (BIT), a digital solution designed to support sustainability, traceability, and certification within bio-based supply chains. Building upon the platform's technical developments and framework modelling described in earlier project phases, D5.3 focuses on the real-world evaluation and user validation of the BIT across diverse European contexts.

The validation process followed a dual approach, combining internal testing by project partners, who simulated the roles of biomass producers, bioindustry companies, and certifiers, with extensive external validation through stakeholder events in Spain, Greece, and Italy. Additional engagement took place through industry associations and open workshops, ensuring broad feedback from end users, industry representatives, and potential certifying bodies. This process assessed usability, usefulness, integrability, and the platform's capacity to address sectoral needs.

Overall, the results indicate that the BIT is intuitive, accessible, and widely perceived as a valuable asset for companies engaged in bio-based value chains. Participants reported an average usability score of approximately 70/100, noting the modern design and ease of navigation. Lower ratings were mainly associated with the complexity of manual data entry, an issue expected to be minimal during real deployments, as most information will be collected automatically through sensors and integrated data sources. Stakeholders expressed confidence in using the BIT and recognised its value for improving traceability, supporting digital product passports, and facilitating compliance with sustainability standards. The BitAdvisor self-assessment mechanism, which is a section within the BIT, was considered particularly helpful for providing actionable feedback and readiness checks for certification. The BIT's visual design, especially its mobile-first accessibility and clear mapping features, was positively received. In addition, the possibility of exploring and documenting complete value chains and visualising environmental and circularity criteria was regarded as addressing a significant transparency gap in the sector. At the same time, stakeholders highlighted the risk that if any company within a chain fails to participate or keep its information up to date, the integrity of the entire value chain representation may be compromised.

Several lessons were drawn that point to future development needs. Certain tasks, such as entering highly complex value chains, still pose challenges and justify continued interface improvements and support features. Integration with company management systems and the expansion of API capabilities will be important for large-scale uptake. Enhancing multilingual support and providing richer contextual help also remain priorities for improving accessibility across diverse user groups.

In conclusion, the validation process confirms that the BIT is a robust and adaptable tool capable of supporting stakeholders in advancing sustainability, transparency, and certification across bio-based sectors. The incorporation of user-driven feedback and iterative improvements ensures that the platform is well positioned for broader deployment and continued evolution in alignment with industry needs.

1 Introduction

This deliverable outlines the validation process of the digital tool BIT (BioReCer ICT Tool), developed within the framework of the BioReCer project, funded by the Horizon Europe programme (call HORIZON-CL6-2021-ZEROPOLLUTION-01-05). This tool is one of the main technological outcomes of the project and is designed to improve the traceability, environmental sustainability, and certification of value chains involving biological feedstock, secondary raw materials.

The validation of BIT addresses the need for an interoperable, transparent digital solution aligned with the principles of the circular economy, the EU Taxonomy Regulation, the Do No Significant Harm (DNSH) principle, and the General Data Protection Regulation (GDPR). Its modular design and "mobile-first" approach allow its use by various user profiles: biomass producers, bio-based industries, certification bodies.

This deliverable documents the methodological approach adopted for the validation of the tool, including:

- The structure and logic of the user interface.
- The technologies used and their integration into the FIWARE ecosystem.
- Internal validation with key consortium users.
- External validation through stakeholder events in four European regions.
- The results obtained in the demonstrative use cases: fishery waste and urban and industrial sewage sludge in Galicia, urban bio-waste in Milan, agricultural residues in Greece, and forest residues in Sweden.

The validation of BIT has been carried out following an iterative and participatory approach, within the framework of the BRIE Living Lab, ensuring the incorporation of the real needs of actors involved in bio-based value chains. The results obtained confirm that BIT is a robust, adaptable, and useful tool to support the transition towards more sustainable, traceable and certified production models in the context of the European bioeconomy.

2 Our approach with the BIT user interface(s)

2.1 A web application

The BioReCer ICT Tool (BIT) represents a comprehensive digital platform designed to support sustainability and circularity assessment, traceability, and certification processes for bio-based feedstocks and products. It serves as the technical pillar of the BioReCer project, providing stakeholders with actionable tools for visualising supply chains, enabling digital tracking throughout product lifecycles, visualising digital product passport (DPP) information, exploring bio-based standards and certificates, and conducting efficient self-assessments.

The development of the BIT UI (BioReCer ICT Tool User Interface) followed an iterative, user-centred design approach that prioritized usability, accessibility, and stakeholder engagement. This section describes the methodological framework employed in developing the web application, including the design principles, tools, and collaborative processes that shaped the interface to meet the diverse needs of biomass producers, bio-industry stakeholders, and certification bodies (CB).

2.1.1 Mobile-first approach

The BIT was designed with a mobile-first philosophy, recognizing the operational realities of bio-based supply chain stakeholders. Many users in the biomass sector—particularly primary producers and field operators—work in environments where mobile devices represent the primary or sole means of digital access. Agricultural producers, forestry workers, and waste management operators often need to access information and input data while on-site at production facilities, storage locations, or during transport operations, where desktop computers are impractical or unavailable.

The mobile-first design strategy influenced several critical aspects of the BIT UI development:

Responsive design architecture: The interface was built using responsive web design principles, ensuring seamless adaptation across device sizes from smartphones to tablets and desktop monitors. This approach guarantees that all functionality remains accessible and usable regardless of the device employed by the user.

Touch-optimized interactions: Interface elements were designed with touch interactions as the primary input method. Buttons, navigation elements, and interactive components were sized and spaced according to mobile usability guidelines, ensuring comfortable and accurate touch targets in challenging field conditions.

Simplified navigation patterns: The mobile-first approach necessitated streamlined navigation structures that minimize cognitive load and reduce the number of steps required to complete common tasks. The interface employs familiar mobile design patterns such as bottom navigation bars, swipe gestures, and hamburger menus to provide intuitive access to key features.

Performance optimization: Recognizing that mobile users may operate under bandwidth constraints, particularly in rural areas where biomass production often occurs, the development team prioritized performance optimization. The application employs efficient

data loading strategies, image optimization, and caching mechanisms to ensure responsive performance even under limited connectivity conditions.

Progressive enhancement: While the core functionality was designed for mobile devices, the interface progressively enhances the user experience on larger screens, taking advantage of additional space to display more contextual information, and detailed data visualisations when viewed on tablets or desktop computers.

The mobile-first approach directly addresses the technical and social challenges identified in the BioReCer project, particularly regarding digital literacy disparities and the need to accommodate diverse operational contexts across the bio-based supply chain. By prioritizing mobile accessibility, the BIT removes barriers to adoption and ensures that all stakeholders, regardless of their technological infrastructure, can participate in enhanced traceability and sustainability assessment processes.

2.1.2 Mockups and prototyping

The development of the BIT UI followed a structured design process that emphasized early visualisation, iterative refinement, and stakeholder feedback integration. Mockups and prototypes played a central role in this process, serving as communication tools between technical developers, project partners, and end-users throughout the design and development lifecycle.

Low-fidelity wireframes: The initial design phase focused on creating low-fidelity wireframes that outlined the basic structure, navigation flow, and content hierarchy of the interface. These wireframes abstracted away visual design details to focus stakeholder attention on fundamental usability questions: How should information be organized? What actions should be prioritized? How should users navigate between different modules?

These early wireframes proved invaluable for identifying potential usability issues before significant development resources were committed. The wireframing process involved iterative cycles where the design team created multiple alternatives for key interfaces, evaluated them against user requirements derived from WP2 and WP4, and selected the approaches that best balanced functionality with simplicity.

High-fidelity mockups: Following validation of the basic structure through wireframes, the design process advanced to high-fidelity mockups that incorporated visual design elements including colour schemes, typography, iconography, and spacing. These mockups provided stakeholders with a concrete representation of the final interface appearance, facilitating more specific feedback on visual hierarchy, branding, and aesthetic preferences.

The high-fidelity mockups served multiple purposes within the development process. For technical developers, they provided detailed specifications for implementation, including precise dimensions, colours, and interaction states. For project partners and stakeholders, they offered a tangible preview of the tool that could be evaluated without requiring functional code, accelerating the feedback cycle and reducing the cost of design changes.

Interactive prototypes: To evaluate user flows and interaction patterns beyond what static mockups could convey, the design team developed interactive prototypes that simulated the behaviour of the final application. These prototypes, while not connected to live data or backend systems, allowed users to click through interfaces, navigate between screens, and experience the intended interaction model.

Interactive prototypes proved particularly valuable for testing complex workflows such as the supply chain exploration feature, where users navigate through multiple levels of relationships between products, transformations, and actors.

Prototyping for mobile contexts: Given the mobile-first design philosophy, particular attention was paid to prototyping the mobile experience. Mobile-specific prototypes were developed to test touch interactions, swipe gestures, and responsive behaviour as screen orientation changed (Figure 1). These prototypes helped identify issues such as insufficient touch target sizes, unclear navigation patterns, and information density problems that might not have been apparent in static mockups or desktop-oriented prototypes.

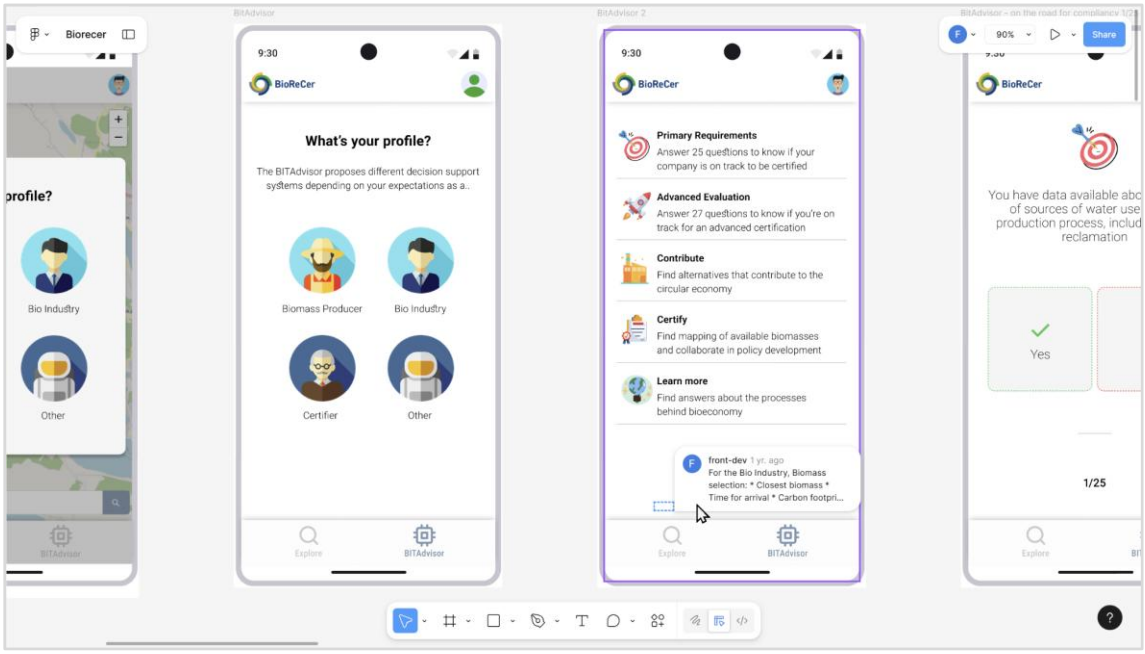


Figure 1. Prototyping with Figma as a collaborative design tool

2.1.3 Use of Figma as a collaborative design tool

The design and prototyping work for the BIT UI was conducted using Figma, a cloud-based collaborative design tool that proved instrumental in supporting the distributed, multi-partner nature of the BioReCer project. Figma's capabilities aligned well with the project's needs for real-time collaboration, version control, and accessibility across organizational boundaries.

Collaborative design environment: Figma's cloud-based architecture enabled simultaneous collaboration among team members distributed across different organizations and geographic locations. Designers, developers, and stakeholders could view, comment on, and iterate on designs in real-time, eliminating the friction associated with file sharing, and asynchronous communication that often plague distributed design processes.

The design system also facilitated communication between designers and developers. Components defined in Figma could be directly referenced during implementation, with developers creating corresponding code components that matched the specifications. This alignment between design and code components reduced implementation errors and ensured that the final product closely matched the approved designs.

2.1.4 Bi-weekly meetings and iterative development

The development of the BIT UI followed an agile methodology characterized by short iteration cycles, to keep the flow of continuous partners' feedback for internal validation. Central to this approach was the establishment of bi-weekly meetings that served as coordination points for the distributed development team and created regular opportunities for progress review and decision-making. Also making sure that we are still on tracks with expectations and do not deviate too much.

The bi-weekly meetings brought together the core development team from EGM (responsible for technical implementation), ANFACO-CEC (providing end-user perspective and coordinating validation activities), and representatives from other consortium partners contributing to specific aspects of the platform development. Meeting agendas typically included progress reports on development activities since the previous meeting, demonstrations of newly implemented features, discussion of technical challenges and proposed solutions, review of various feedback, and planning of priorities for the next iteration.

Rather than attempting to implement complete modules in their entirety before seeking feedback, the development team adopted an approach of incremental delivery. A feature would progress through multiple iterations, with each cycle adding functionality, refining usability, or addressing issues identified in the previous version.

For example, the supply chain exploration feature evolved through several iterations. An early version provided basic visualisation of product relationships, displaying input and output materials for a single transformation. Subsequent iterations added timeline visualisation, geospatial mapping of supply chain stages, and interactive filtering capabilities. Each addition was demonstrated during bi-weekly meetings, evaluated against user requirements, and refined based on feedback before the next increment was planned.

Each bi-weekly meeting included live demonstrations of newly implemented or modified features. The demonstration format encouraged critical evaluation from diverse perspectives. Technical stakeholders could assess architectural decisions and implementation quality, while domain experts could evaluate whether features adequately addressed bio-based supply chain needs.

2.2 User testing sessions during stakeholders' events

To evaluate the usability, usefulness, and overall user experience of the BIT, structured user testing sessions were conducted during BioReCer stakeholder events. These sessions provided early feedback on the interface design, feature prioritization, and user experience across different devices, informing subsequent development iterations and helping ensure that the final tool would meet the practical needs of its intended users.

Unlike the formal external validation activities described in Section 4 (which focused on validating the tool with representative end-users in specific case study contexts), the user testing sessions described in this section were conducted during internal project events with consortium partners and early stakeholders. These sessions occurred at the 4th Project Executive Board (PEB) meeting in Sweden (June 2024) and the 5th PEB meeting in Milan, Italy (October 2024), providing opportunities to gather feedback from diverse stakeholders during key project milestones.

Due to the last multi-stakeholders meeting being an online event (September 2025), it was not possible to organize a proper user testing session such as the ones from Sweden

and Italy. Nevertheless, a thorough showcase of the tool was done before gathering feedback. The results for this event are presented separately in section 2.2.3 below.

2.2.1 Test protocol for Sweden and Italy

The user testing sessions conducted in Sweden and Italy followed a structured protocol designed to systematically evaluate key aspects of the BIT UI while accommodating the constraints of stakeholder event settings.

Test objectives: The testing protocol specified five primary objectives that guided session design and data collection:

1. Evaluate interface usability: Assess whether participants could complete common tasks using the BIT UI, identify sources of confusion or difficulty, and measure the efficiency with which users accomplished goals.
2. Evaluate tool usefulness: Determine whether stakeholders perceived the BIT features as valuable for their work, whether the tool addressed real needs in bio-based supply chain management, and whether participants anticipated using the tool in their operations.
3. Evaluate interface design perception: Gather feedback on the visual design, information architecture, and overall aesthetic appeal of the interface to ensure that the tool projected appropriate professionalism and inspired user confidence.
4. Evaluate tool experience across different devices: Test the mobile-first design on actual mobile devices that participants brought to the events, identifying device-specific usability issues and validating responsive design implementations.
5. Prioritize features to develop: Identify which planned features stakeholders considered most valuable, helping the development team make informed decisions about resource allocation and development sequencing.

Target user profiles: The testing protocol explicitly targeted two primary user profiles based on the BioReCer framework:

1. Biomass producers: Stakeholders primarily linked to the forestry sector in the Swedish context, and representatives from various sectors (fishery, urban waste, agriculture) in the Italian context. These users would employ the BIT for self-assessment, compliance monitoring, and product registration.
2. Bio-industry companies: Representatives from bio-industry organizations that process biomass feedstocks into value-added products. These users would utilize the BIT for product search, supply chain exploration, and sustainability assessment of potential suppliers.

Session structure and timing: The testing sessions were integrated into the stakeholder event agendas with careful attention to timing constraints. The protocol specified a compact format that respected participants' limited availability:

- Introduction and presentation (10 minutes): A brief overview of the BIT, its objectives, and the testing process. Participants received context about what they would be testing and how their feedback would inform development.
- Hands-on testing (20 minutes): Participants interacted with the BIT on their own devices, following scenario-based tasks that guided them through key features. Test facilitators observed participants, noted difficulties, and were available to answer questions without influencing user behaviour.

- Discussion and feedback (10 minutes): A structured group discussion where participants shared their experiences, identified issues, suggested improvements, and provided feedback on feature prioritization.

This 40-minute total duration was designed to fit within stakeholder event schedules while providing sufficient time for meaningful evaluation.

Scenario-based testing approach: Rather than simply asking participants to explore the interface freely, the protocol employed scenario-based tasks that simulated realistic use cases. For example, participants might be given a scenario such as: "*You've just heard about this new application that lets you explore products' life cycles. You want to know more about it, so you go ahead and create a new user account. Explore a product and try to find information about its environmental impact*."

This scenario-based approach had several advantages. It provided participants with clear goals and context, making the testing experience more engaging and realistic. It ensured that all participants evaluated the same core functionality, facilitating comparison of experiences. It revealed whether users could discover and understand features without explicit instruction, assessing the interface's intuitiveness.

Here are some example scenarios that we used:

- Biocrude oil
  - *"As a biomass producer, you want to see an example based on a biocrude oil. You want to find what were the raw materials used to generate a specific biocrude oil."*
- Product's origins
  - *"As you were exploring the application, you saw that different batches of sawdust were used in the biocrude oil transformation process. Now you want to know if it's possible to evaluate the biomass origins of the biocrude oil. And what are the proportions used?"*
- Transportation
  - *"In this scenario, you would like to evaluate the CO_2 emissions due to transportation used in the making of the biocrude oil. You want to consider all the previous products the biocrude oil has originated from. "*

Figure 2. Presentation of the scenarios to the Swedish stakeholders

Data collection methods: The protocol specified multiple data collection methods to capture both quantitative and qualitative feedback:

- Observation notes: Facilitators observed participants during testing, noting where they encountered difficulties, which features they found intuitive, and how they navigated the interface.
- Questionnaires: Participants completed brief questionnaires assessing their experience across dimensions such as ease of use, usefulness, design quality, and device compatibility. The questionnaires employed both rating scales (to generate quantitative data) and open-ended questions (to capture detailed feedback).
- Group discussion: The facilitated discussion allowed participants to elaborate on their experiences, react to others' observations, and engage in dialogue about priorities and preferences. This qualitative data provided context and nuance beyond what questionnaires could capture.
- Feature prioritization exercise: Participants were asked to rank planned features according to their perceived value, helping the development team understand which capabilities stakeholders considered most important for their work.

Differences between Sweden and Italy sessions: While both testing sessions followed the same overall protocol, some adaptations were made between the Swedish (June 2024) and Italian (October 2024) sessions based on the evolution of the BIT and lessons learned from the earlier session.

The Swedish session, conducted earlier in the project, focused on more fundamental interface concepts and navigation patterns. The testing materials were relatively early-stage that illustrated core functionality but lacked detailed implementation of advanced features. Feedback from this session informed significant design refinements before the Italian session.

By the time of the Italian session in October 2024, the tool had evolved substantially, incorporating feedback from the Swedish testing and reflecting additional development work. The Italian testing therefore evaluated more refined designs and could focus on more advanced features and interactions. The testing materials for Italy included more complete representations of features such as the supply chain timeline, circularity indicators, and the BitAdvisor self-assessment tool.

2.2.2 Results from Sweden and Italy testing sessions

This section synthesizes the key findings from both testing sessions. Overall, participants from both testing sessions generally found the BIT UI intuitive and navigable, with most users able to complete the scenario-based tasks without significant difficulty. The mobile-first design approach proved effective, with participants commenting positively on the interface's responsiveness and ease of use on smartphone screens.

Stakeholders from both sessions expressed strong interest in the BIT and indicated that it addressed genuine needs in bio-based supply chain management. Several specific aspects of usefulness were highlighted:

- Supply chain visibility: Both biomass producers and bio-industry representatives found the supply chain exploration features particularly valuable. The ability to trace products backward to their origins and forward to derived products was seen as addressing a significant transparency gap in current practices. Participants noted that such visibility could support sustainability claims, facilitate regulatory compliance, and enable more informed sourcing decisions.

- Self-assessment tool (BitAdvisor): Biomass producers responded positively to the BitAdvisor questionnaire for evaluating certification readiness. They appreciated the structured approach to assessing compliance with BioReCer framework requirements and found the recommendations for improvement actionable and relevant. Some participants noted that the tool could help them identify gaps in their sustainability practices before engaging with certification bodies, potentially reducing audit costs and preparation time.
- Product search: Bio-industry representatives particularly valued the product search functionality that would allow them to discover biomass feedstocks based on location, type, and sustainability scores.
- Circularity indicators: The automatic calculation and display of circularity indicators received positive feedback from stakeholders interested in demonstrating the circular economy credentials of their products. However, some participants requested clearer explanations of how indicators are calculated proposing the addition of contextual help and/or benchmark comparisons.

The feature prioritization insights conducted during both sessions revealed which planned features stakeholders considered most important for their work.

- High priority features (consistently ranked as most important):
  - Product search and discovery functionality
  - Supply chain traceability and visualisation
  - BitAdvisor self-assessment questionnaires
  - Carbon footprint calculation and display
- Medium priority features (considered valuable):
  - Circularity indicator calculation
  - Export and reporting capabilities
- Lower priority features (nice to have but not essential for initial adoption):
  - Advanced data analytics and dashboards
  - Multilingual support (beyond English and basic partner languages)

Participants generally responded positively to the visual design of the BIT UI, describing it as modern, professional, and appropriate for the business context. Specific design elements that received positive feedback included:

- Colour scheme: The use of green tones associated with sustainability and bio-based products was seen as appropriate and appealing.
- Icon design: Icons were generally well-understood and helped users quickly identify functions without reading text labels.
- Map-based visualisations: The integration of geographic maps for product location and supply chain visualisation was particularly well-received, with multiple participants noting that spatial representation made complex supply chains easier to understand.

The Swedish testing, conducted earlier with a more preliminary tool, generated more fundamental feedback about navigation structure, feature organization, and basic interaction patterns. Swedish participants, from the forestry sector, particularly emphasized the importance of offline functionality for field use where network connectivity might be limited. The Italian testing, conducted later with a more refined tool, generated more specific feedback about feature details, data presentation, and advanced functionality. Italian participants, representing a more diverse set of sectors, provided valuable insights into how different types of biomass producers might use the tool differently.

2.2.3 Results from the last online multi stakeholders meeting

More details on this event can be seen in deliverable D4.4 Final report on the whole development of the BRSP. But to summarize, some important feedback about potential evolutions for more added value emerged from the discussions, such as:

- The possibility to upload documents. Especially, for instance, during an audit process.
- Taking into account certification presence when searching for products.
- Adding simulation capabilities to explore "What if" scenarios, and to instantly show the impact of changes on sustainability.

During this event and the local stakeholders events, the System Usability Scale was used to evaluate the usability of the tool, based on effectiveness (can users successfully achieve their objectives), efficiency (how much time and effort are necessary in achieving those objectives) and satisfaction. The questions use a Likert 1 to 5 scale: 1 meaning "strongly disagree" and 5 meaning "strongly agree".

Table 1. Results of System Usability Scale questions at the last online multi stakeholders meeting

Question	Score
1. I think that I would like to use this system frequently.	3.7
2. I found the system unnecessarily complex	2.5
3. I thought the system was easy to use.	3.4
4. I think that I would need the support of a technical person to be able to use this system.	3.2
5. I found the various functions in this system were well integrated.	3.9
6. I thought there was too much inconsistency in this system.	2.5
7. I would imagine that most people would learn to use this system very quickly.	3.7
8. I found the system very cumbersome to use.	2.5
9. I felt very confident using the system.	3.4
10. I needed to learn a lot of things before I could get going with this system.	3.1

2.3 The administration interface (Twin·Picks)

While the BIT UI described in previous sections focuses on data visualisation, product exploration, and sustainability assessment for end-users, the tool also requires robust administrative capabilities for data management, access control, and system configuration. These administrative functions are provided through a complementary interface called Twin·Picks, which serves as the backend management environment for the BIT.

Twin·Picks is an administrative interface designed to facilitate the complex tasks associated with managing a data platform based on NGSI-LD digital twin concepts. The interface addresses several critical operational needs that are distinct from the end-user experience but essential for tool operation.

2.3.1 Data provisioning and entity management

The primary function of Twin·Picks is to support the creation, management, and lifecycle administration of NGSI-LD entities within the Stellio Context Broker. While end-users interact with data through the BIT UI's visualisation and search capabilities, administrators and data providers use Twin·Picks to initially provision data into the system, update entity information, and manage data quality.

Twin·Picks organizes data management around the concept of "use cases", collections of related entities that represent a specific supply chain, product line, or operational context. Use cases provide an organizational structure that simplifies data management and enables context-specific configurations. For example, each case study leader from the BioReCer project has their own use case to separate their supply chain data and to not visually overlap during the provisioning process.

Through Twin·Picks, administrators can create new use cases, configure their types (such as "Biofertilizer production," "Fish oil processing," or "Sewage sludge valorisation"), and manage the entities associated with each use case. This organization helps users locate relevant data and provides a framework for applying consistent configurations across related entities.

The administration interface includes a guided provisioning module that simplifies the complex process of creating properly structured NGSI-LD entities. Rather than requiring users to manually construct JSON-LD payloads that conform to the BioReCer data model, Twin·Picks presents dynamic forms that guide users through entity creation, validate inputs, and ensure that all required relationships and attributes are properly defined. This guided approach reduces errors, accelerates data onboarding, and makes the system accessible to administrators without deep technical expertise in NGSI-LD specifications.

The structured workflow that guides users through the multi-step process of provisioning a complete supply chain representation is as follow:

1. Product definition: Users begin by creating product entities, specifying attributes such as product name, type (main product, residue, or by-product), amount, and last known storage location. The interface validates inputs and provides helpful guidance about required fields.
2. Production system specification: Users define the production systems (facilities, equipment, or processes) where products are produced or processed. This includes specifying system location (with an integrated map interface for selection), the transformation applied, and relationships to corporate entities.
3. Corporate entity linking: Users can either create new corporate entities (representing their own companies or partners) or link to existing entities if their organizations are already registered. This entity reuse capability prevents duplication and maintains data consistency.
4. Storage, transport, and logistics: The workflow guides users through defining storage locations, transporters, and travel routes that products follow through the supply chain. The interface supports route calculation and carbon footprint estimation based on transport mode and distance.
5. Transformation and process details: For products that undergo processing, users specify transformation details including inputs consumed, outputs generated, energy requirements, chemical requirements, and other process parameters relevant to environmental impact assessment.
6. Review and synchronization: After provisioning entities locally within the interface, users review the complete set of entities, verify relationships, and synchronize them with the Stellio Context Broker, making the data available to the broader platform.

Throughout this workflow, Twin·Picks provides real-time validation, indicates which steps are mandatory versus optional, tracks progress through the provisioning process, and allows users to save partial work and return later to complete provisioning.

2.3.2 Device management for IoT integration

Although not extensively utilized in early project stages, Twin·Picks includes a device registration module that supports integration with IoT sensors and connected devices. As bio-based supply chains increasingly employ sensors for monitoring (temperature, humidity, moisture content, etc.), this module will facilitate registering devices, configuring their communication parameters, and mapping sensor data to appropriate NGSI-LD entities. The module leverages a collectively maintained device catalogue that contains decoding scripts and communication protocol details for known device types.

Data upload was mostly done manually using the device provisioning module by stakeholders and case study leaders. However, the tool is fully ready for automatic ingestion. For example, the data generated by the hyperspectral imaging (HSI) system used by ANFACO-CEC was uploaded automatically thanks to the Stellio API and could be visualised in real-time in the related Digital Product Passport of specific registered algae product samples.

2.3.3 Access rights and permissions management

A critical security requirement for the BIT is fine-grained control over data access. Bio-based supply chains involve multiple stakeholders with varying relationships—competitors, suppliers, customers, and certification bodies—each with legitimate but different needs for data access. Twin·Picks provides comprehensive access rights management capabilities that allow data owners to precisely control who can view, modify, or administer their entities.

The rights management module enables several access control patterns:

- Entity-level permissions: Data owners can grant specific users or user groups different authorization levels (READ, WRITE, or ADMIN) for individual entities. This granular control allows, for example, a biomass producer to share product information with potential customers (READ access) while allowing their own staff to modify that information (WRITE access) and reserving administrative rights for designated managers (ADMIN access).
- Scope-level permissions: To simplify permission management for collections of related entities, Twin·Picks supports scope-level access control. A scope might represent a complete use case, a product family, or a business unit. Granting permissions at the scope level automatically applies those permissions to all entities within that scope, reducing the administrative burden of managing permissions individually.
- Global access policies: For entities that should be publicly accessible (such as generic reference data or entities shared for transparency purposes), Twin·Picks allows data owners to designate entities as publicly readable by any authenticated user.

This flexible permission model addresses the challenge of balancing transparency with proprietary information protection—a tension identified as a significant social challenge in bio-based supply chain digitalization, and also regularly mentioned during both testing sessions.

2.3.4 Relationship to BIT UI

Twin·Picks and the BIT UI (BioReCer ICT Tool User Interface) are complementary components of the BIT ecosystem. Twin·Picks focuses on data creation, management, and access control—activities typically performed by data owners and platform administrators. The BIT UI focuses on data discovery, visualisation, and utilization—activities performed by a broader user base including potential customers, certification bodies, and researchers.

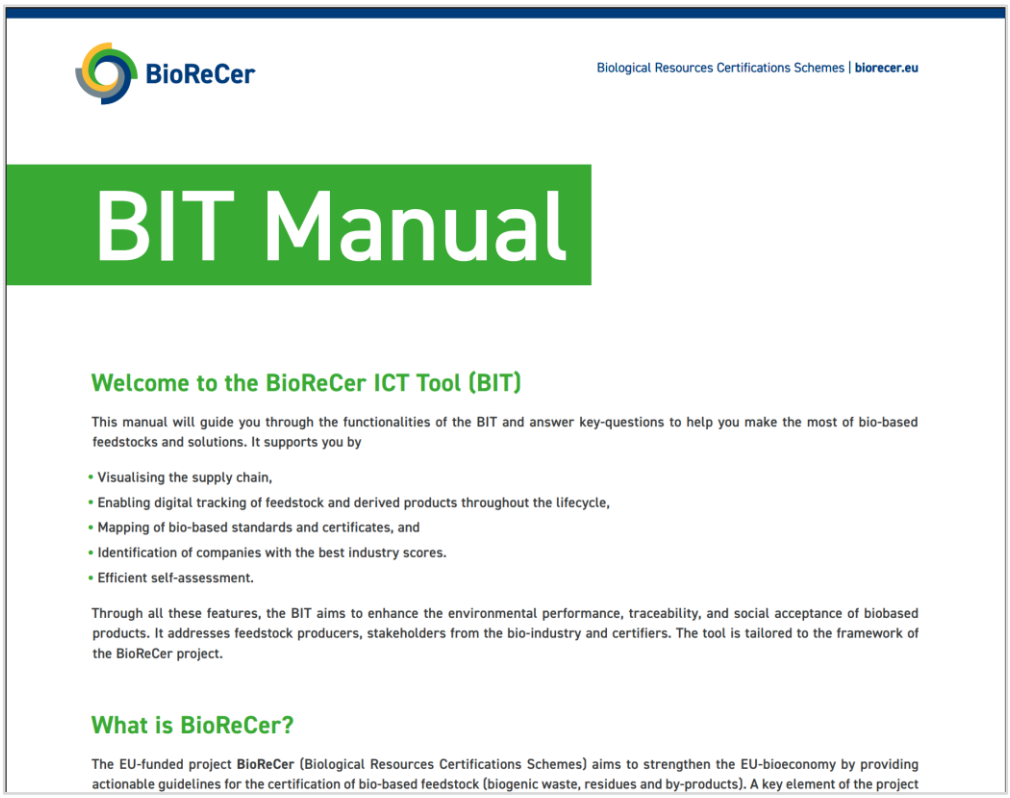
Data provisioned through Twin·Picks becomes immediately available for visualisation and search in the BIT UI (subject to access control policies). Conversely, when end-users interact with data through the BIT UI—for example, registering their companies or answering BitAdvisor questionnaires—that data is stored via the same backend systems that Twin·Picks manages, ensuring consistency across interfaces.

2.3.5 User experience and accessibility

While Twin·Picks is an administrative interface targeting more technical users than the BIT UI, end-user interface, it nonetheless emphasizes usability and accessibility. The interface employs clear visual organization, contextual help, and workflow guidance to make complex administrative tasks manageable. Unlike many administrative interfaces that assume technical expertise, Twin·Picks attempts to make NGSI-LD data management accessible to domain experts (biomass producers, supply chain managers) who may lack specialized knowledge of semantic web technologies.

2.3.6 Training and documentation

Given the administrative complexity that Twin·Picks manages, comprehensive user documentation has been developed to support administrators and data providers. The BIT Manual [1] includes detailed guidance on using Twin·Picks for data provisioning, access management, and other administrative tasks. Additionally, contextual help within the interface provides just-in-time guidance for specific tasks. The BIT manual is currently available online, in English and Spanish, here: https://biorecer.eu/biorecer-ict-tool-bit/


BioReCer

Biological Resources Certifications Schemes | biorecer.eu

BIT Manual

Welcome to the BioReCer ICT Tool (BIT)

This manual will guide you through the functionalities of the BIT and answer key-questions to help you make the most of bio-based feedstocks and solutions. It supports you by

- Visualising the supply chain,
- Enabling digital tracking of feedstock and derived products throughout the lifecycle,
- Mapping of bio-based standards and certificates, and
- Identification of companies with the best industry scores.
- Efficient self-assessment.

Through all these features, the BIT aims to enhance the environmental performance, traceability, and social acceptance of biobased products. It addresses feedstock producers, stakeholders from the bio-industry and certifiers. The tool is tailored to the framework of the BioReCer project.

What is BioReCer?

The EU-funded project **BioReCer** (Biological Resources Certifications Schemes) aims to strengthen the EU-bioeconomy by providing actionable guidelines for the certification of bio-based feedstock (biogenic waste, residues and by-products). A key element of the project

Figure 3.Beginning of the BIT Manual's English version

Twin·Picks represents a critical component of the BIT architecture, providing the administrative capabilities necessary for sustainable platform operation. By making complex data management tasks accessible through guided workflows and intuitive interfaces, Twin·Picks enables bio-based supply chain stakeholders to actively participate in platform data provisioning rather than requiring specialized technical expertise. This democratization of data management supports the BioReCer vision of collaborative, transparent supply chain digitalization.

3 New features and improvements of the BIT platform

This section details the significant enhancements and new functionalities implemented in the BIT UI following the deliverable D5.2 Models for context information, decision support and visualisation templates. These improvements represent a substantial evolution in the platform's capabilities, addressing key stakeholder requirements identified through co-creation processes, and through internal and external validation activities.

The BIT has undergone continuous development since the D5.2 deliverable, with particular focus on enhancing user experience, expanding data integration capabilities, and strengthening decision support functionalities. The tool maintains its flexible integration approach and its foundation on the Stellio Context Broker for data management and NGSI-LD context data model, which serve as the backbone for all new features to seamlessly integrate with existing functionalities, while ensuring interoperability.

3.1 Enhanced Environmental Assessment Capabilities

The tool now incorporates a greenhouse gas emissions calculation methodology that extends beyond traditional scope assessments to include emissions from by-products throughout the supply chain. This enhancement addresses a critical gap identified during stakeholder consultations, where traditional carbon footprint calculations failed to account for the circular nature of bio-based supply chains.

The new calculation method leverages the NGSI-LD data model's relationship capabilities to track material flows and transformations across the entire value chain. The system automatically calculates transport carbon footprints by aggregating data from all upstream transportation activities, which occurred before the selected product was generated.

Transportation calculations have been refined to provide more precise emissions estimates using OpenRoute service integration, which accounts for actual road networks and optimal routing strategies. For maritime transport, the system uses straight-line distance calculations while acknowledging the limitations of this approach due to variable shipping routes influenced by weather and ocean currents.

Also, it is important to note that at this stage, even if not directly visible in the BIT UI, the tool is ready to allow the calculations of all the energy consumption accounting for each upstream transformation process and by-product generation, and storage costs.

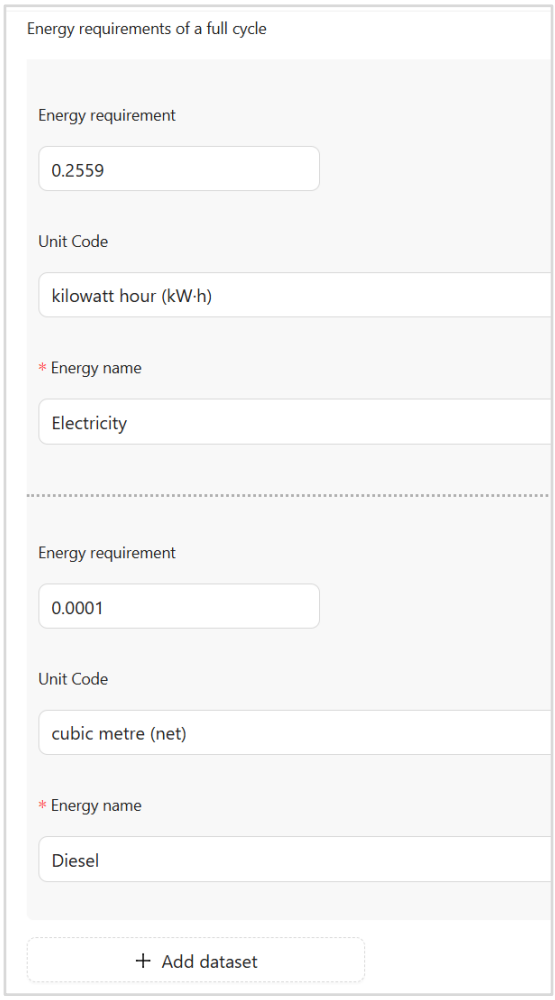


Figure 4. Screenshot of the administration interface form for a Transformation

Indeed, the tool already includes the necessary inputs control for this type of information. The screenshot above shows an example of how this information can be entered, with a Transformation called: "PB production process (A100-400)", from the Greek case study.

It's not possible to accurately estimate the Green House Gases (GHG) emissions impact of these energy consumptions without knowing how the electricity was produced (e.g., nuclear vs. coal). Still, the gathered data from all transformation processes and by-product storages can give users valuable insights and help them make more informed estimates.

Therefore, it could be useful to explore how the data model could incorporate information about energy production methods.

3.2 Certification and Compliance Framework

A dedicated certifications section has been implemented to provide comprehensive tracking and management of sustainability certifications throughout the supply chain. This section integrates with the existing Certificate entity in the NGSI-LD data model, allowing users to:

- View current certification status for products and processes.

- Track certification expiration dates and renewal requirements.
- Monitor compliance with multiple certification schemes simultaneously.
- Access detailed certification documentation and audit reports.

The certification section supports integration with established certification frameworks including ISCC (International Sustainability and Carbon Certification) and provides pathways for future integration with emerging bio-based certification schemes.

3.3 QR Code Integration for Digital Product Passport (DPP) Access

A significant usability improvement includes the implementation of QR code functionality that enables quick and easy access to product information through the Digital Product Passport (DPP). This feature addresses practical challenges identified during user testing sessions, where stakeholders require immediate access to product data in field conditions or during supply chain handovers.

The QR code system integrates with the existing product identification framework, providing instant access to:

- Complete product traceability information
- Sustainability metrics and certifications
- Supply chain visualisation
- Hyperspectral analysis data where available

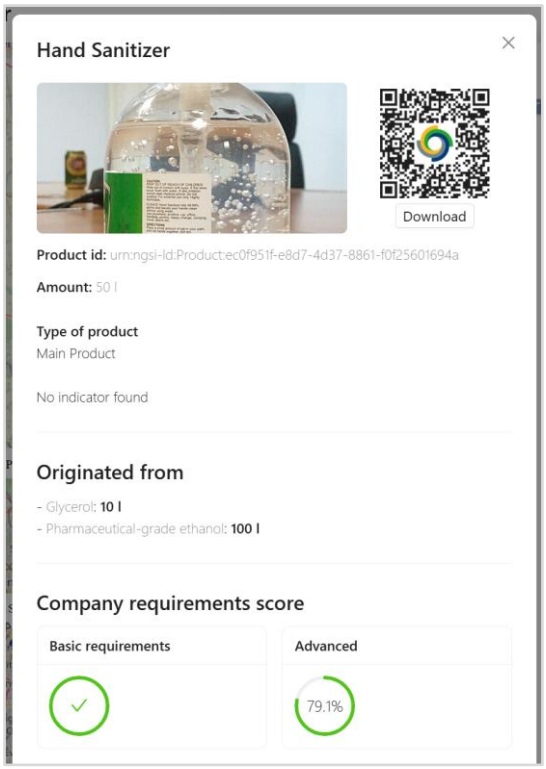


Figure 5. Screenshot of a hand sanitiser Digital Product Passport in the BIT UI

3.4 Link between Product and the Company's Scores

The integration within the DPP of company performance scores from the BitAdvisor decision support system represents a major advancement in the platform's analytical capabilities. As shown in the figure above, a new section is dynamically added to the DPP as soon as the company generating the product of interest has logged its responses to questionnaires covering basic and advanced sustainability requirements.

3.5 More Precise Route Calculations

The BIT now incorporates advanced routing algorithms using OpenRoute service integration to provide highly accurate distance and emissions calculations. This improvement addresses previous limitations where route calculations relied on simplified distance estimates that did not account for actual road networks and traffic conditions (Figure 6).

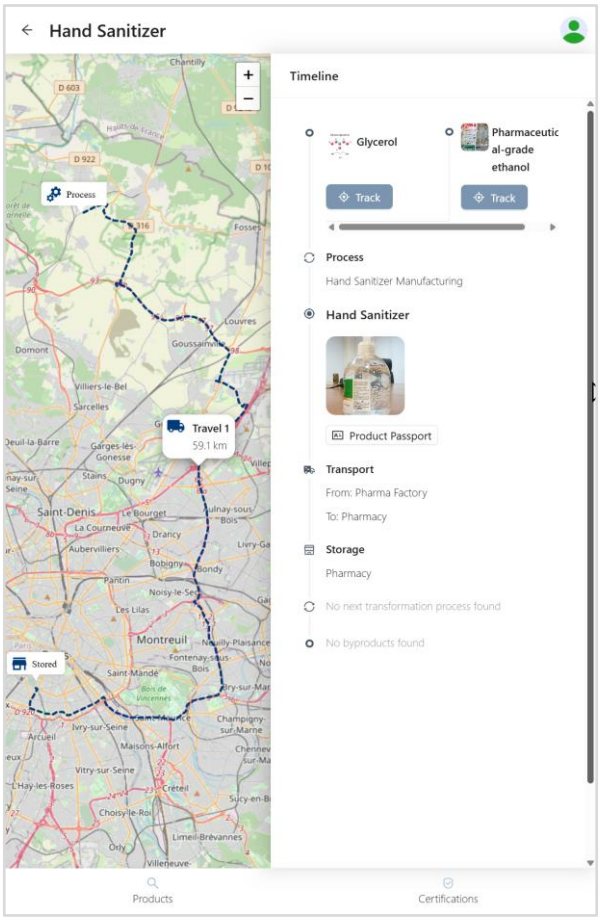


Figure 6. Screenshot showing the precise route calculation of product's travels

3.6 Implementation of Hyperspectral Data in DPP

A HSI data integration system has been implemented within the DPP framework (Figure 7). This advanced data integration capabilities allows a deep product quality assessment and characterization.

The HSI integration includes several new entities in the NGSI-LD data model:

- Hypercube Entity: Stores spectral hypercube data with spatial resolution information.
- Camera Entity: Defines HSI sensor specifications and technical parameters.
- Analysis Entity: Contains analytical information derived from spectral analysis.
- PredictionModel Entity: Represents algorithms for product characteristic prediction.

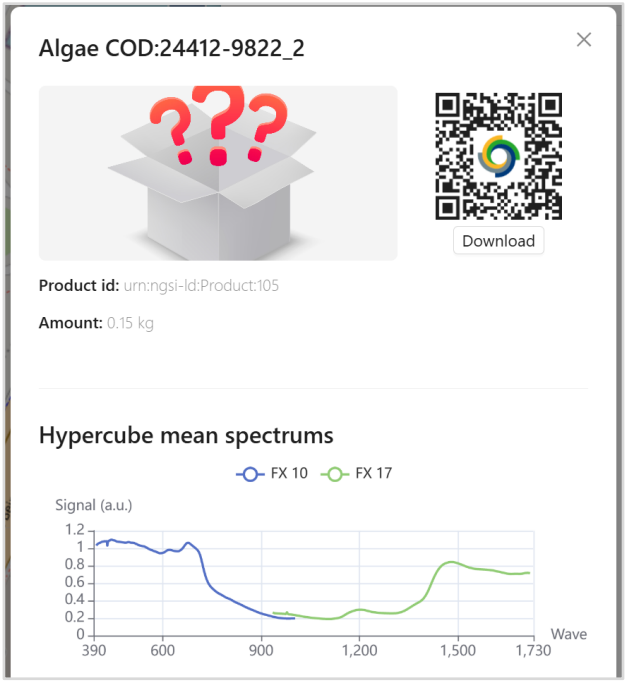


Figure 7. Snippet screenshot of the DPP of an algae's sample

This integration enables quality assessment of bio-based products and predictive modelling of product characteristics based on spectral signatures. It also opens the door to traceability through unique spectral fingerprinting.

3.7 Circularity indicators calculation in DPP

Product's Circularity indicators (CI) calculation results were implemented in the DPP as well. Those are dynamically calculated and displayed as soon as enough data has been gathered and/or if the minimum requirements were met in terms of model definition. For example, for a specific type of CI to be calculated, a lot of context information must be known from the system such as the type of product (main product, residue or by-product, raw material) and the type of Corporation generating the product (or its position in the supply chain) such as: primary producer, manufacturer, processor, waste manager. And then information about the product itself must be known such as "the percentage (%) of the total dry mass of the residue or by-product that is considered as unavoidable" among others.

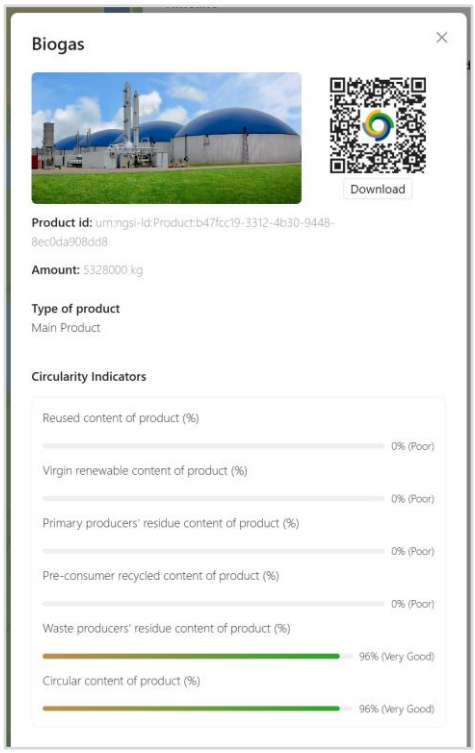


Figure 8. Snippet screenshot of a product with CI

The enhanced BioReCer DPP provides stakeholders with transparent access to comprehensive product information including origin traceability, processing history, environmental impact assessments, and certification status. It pushes towards an alignment with the emerging European Union's Digital Product Passport regulations, "fostering a more open and responsible marketplace" (https://data.europa.eu/en/news-events/news/eus-digital-product-passport-advancing-transparency-and-sustainability).

3.8 "Looking for Audit" Signal Marker

An innovative marketplace functionality allows corporations to signal their readiness for sustainability audits through a toggleable marker system. This feature facilitates connections between companies seeking certification and available certification bodies, streamlining the certification process and promoting transparency.

3.9 List of Corporation's BitAdvisor Scores

A dedicated section has been developed specifically for certification bodies, providing access to comprehensive industry sustainability assessments, by displaying an ordered list of registered Corporations. Those with the highest rating are displayed higher, showing both results on basic requirements and advanced requirements.

It's also possible to visualise whether a company in the list is looking for an audit or not thanks to the toggleable signal system.

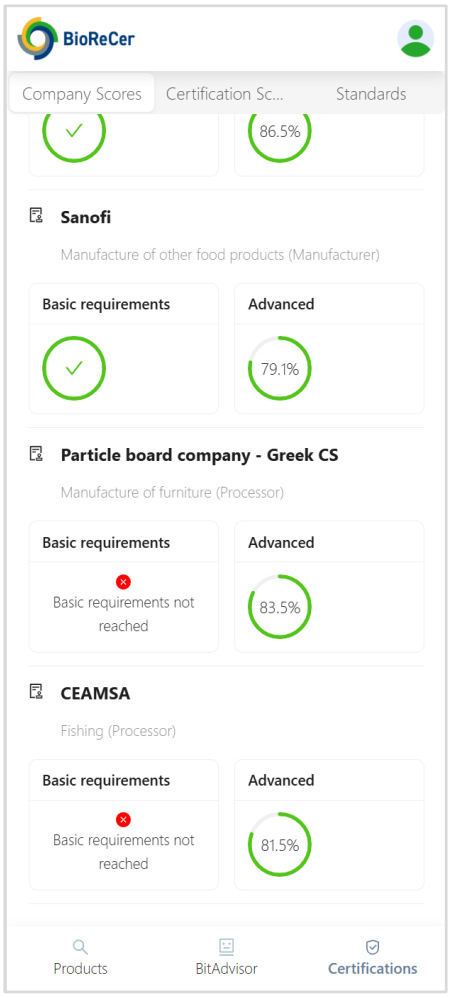


Figure 9. Screenshot of the Corporation's list view for Certification bodies

The view also provides access to a catalogue of certifications and standards relevant to the bio-economy. Those documents can be browsed by keywords and areas of effect. A small description appears for each one to quickly identify those of interest and a direct link is available to delve into the full official document if needed.

Several improvements to this certification body view were identified as necessary during internal validation, as described in the sub sections 4.1.

3.10 Technical Infrastructure Enabling Platform Evolution

3.10.1 Stellio Context Broker: The Foundation for Advanced Functionality

All of these new features and improvements were made possible thanks to continuous behind-the-scenes development work on the Stellio Context Broker, the core backend server that forms the technological backbone of the BIT. The Stellio Context Broker serves as a sophisticated data management engine that handles contextualized information in both temporal and spatial dimensions, providing the robust foundation necessary for the advanced functionalities described above.

It manages the complex relationships between entities throughout the bio-based supply chain and provides data management capabilities including real-time data provisioning, querying mechanisms, and fine-grained access control systems that enable selective data sharing while protecting sensitive business information. The broker's ability to handle temporal data allows for tracking changes in product characteristics over time, while its spatial capabilities support geographical analysis of supply chains and environmental impacts.

The context broker exposes a powerful REST API that serves as the primary interface for all BIT components, enabling seamless data exchange between the user interface, decision support systems, and external data sources. This API supports complex queries that can traverse relationship chains across multiple entities, enabling features such as complete supply chain traceability from finished products back to original biological feedstocks. The broker's advanced access control mechanisms support entity-level, type-level, and scope-level permissions, ensuring that stakeholders can selectively share specific sustainability metrics without exposing proprietary process details or commercial relationships.

3.10.2Cloud-Ready Infrastructure and CI/CD Pipeline

Equally important to the tool's success has been the extensive work on infrastructure modernization and the implementation of comprehensive CI/CD pipelines that make the entire BIT "cloud-ready". This infrastructure transformation involved containerizing all required components using Docker technology, implementing automated versioning systems, and establishing robust deployment pipelines that ensure reliable and efficient platform operation.

The infrastructure work included the development of a comprehensive containerization strategy that packages each component of the BIT, including Keycloak for authentication, Stellio Context Broker for data management, Apache NiFi for data acquisition, and the various user interface components, into standardized Docker containers. This containerization approach ensures consistent deployment across different environments, simplifies maintenance operations, and provides the scalability necessary to support growing user bases and data volumes.

The CI/CD pipeline implementation leverages a combination of Jenkins for orchestration, GitHub Actions for code quality checks and automated testing, and Ansible for infrastructure automation. This pipeline ensures that code changes undergo rigorous testing before deployment, with automated builds, unit tests, integration tests, and SonarQube code quality analysis. The automated deployment process includes both development and production environment management, with clear separation to minimize disruptions and identify potential issues before they affect end users.

The infrastructure also includes monitoring and alert systems that track tool performance and automatically notify administrators of any issues. The entire system is designed for cloud deployment on OVH Cloud infrastructure, with virtual machine distribution optimized for performance and security. This cloud-ready architecture ensures that the BIT can scale efficiently to meet growing demand while maintaining the high availability and performance standards required for certification and decision support applications.

4 Validation of BIT (T&T)

The validation of the tool is approached from a dual perspective. On one hand, an internal validation is carried out by the project partners, who assume three key roles: biomass producer, bioindustry, and certifier. On the other hand, an external validation is considered, involving stakeholders who have not directly participated in the development of the tool, thereby providing an independent and complementary viewpoint.

4.1 Internal validation

This section will include the direct experience of some project partners when interacting with the application, particularly during the process of uploading value chains into the tool. The same structure or questionnaire used in the external validation with stakeholders can be followed to ensure consistency in the evaluation.

4.1.1 Biomass producer

Internal validation for the Biomass Producer uses case relies on researchers' interactions with the tool during application testing and the preparation of dissemination materials.

First of all, the process for registering the company and the user for the first time is well designed. Many of the fields include dropdown menus to assist the user, and the company profile is clearly defined, even with small illustrations that explain each profile. This helps users decide which profile best fits their case.

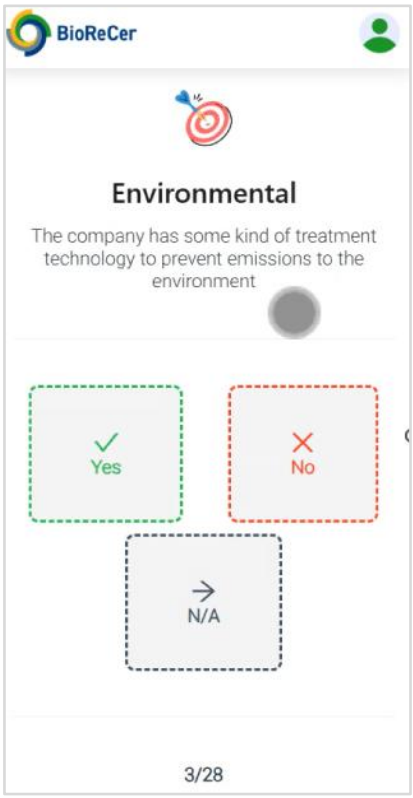


Figure 10. Screenshot of BitAdvisor tool

The user experience with the BitAdvisor tool is friendly and intuitive. The interface presents a set of 28 general-purpose questions that are easy to answer. Additionally, the application provides tailored recommendations to support certification processes, including the specific information typically required by an auditor in a real-world scenario. This guidance is clear and highly useful, especially for users with limited experience in the field.

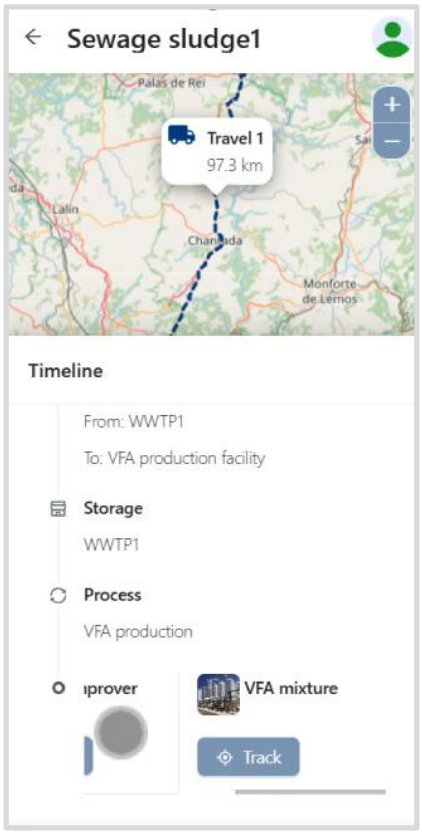


Figure 11. Screenshot showing the monitoring process of a value chain within the tool

The tool for exploring by-products and value chains is intuitive and user-friendly. It features an interactive map that displays detailed information about each product, including its location. The Digital Product Passport, along with data on emissions and analytical parameters, is well-structured and clearly presented, allowing for efficient access and interpretation.

Among the available functionalities, uploading a new value chain in the tool is likely the most complex task, requiring more user input and attention compared to other features. As a general strategy, presenting the necessary entities in an orderly way when uploading a value chain to the BIT helps ensure clarity and usability.

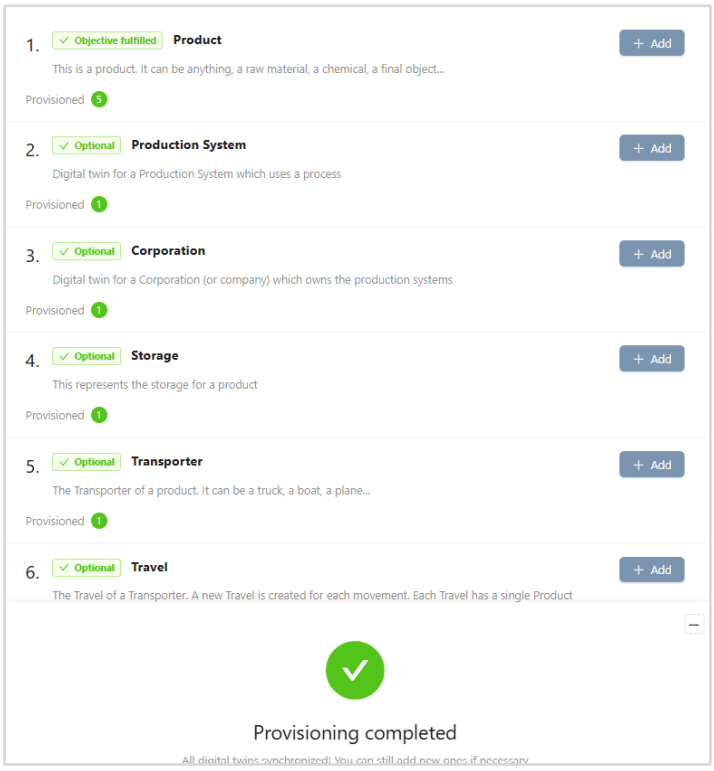


Figure 12. The administration interface (Twin·Picks) for defining and uploading a new value chain within the tool

In this context, it is crucial for the user to have a clear vision of how to translate their process into the model. This requires an understanding of the available entities, and the specific information needed for each of them. Therefore, it is important that new users consult the BIT manual or seek assistance from experienced users to correctly upload a value chain.

Future upgrades could benefit from the implementation of a more visual interface to facilitate the uploading of value chains. For example, the interface could provide various templates with predefined entities, facilitating the efficient upload and organization of value chains.

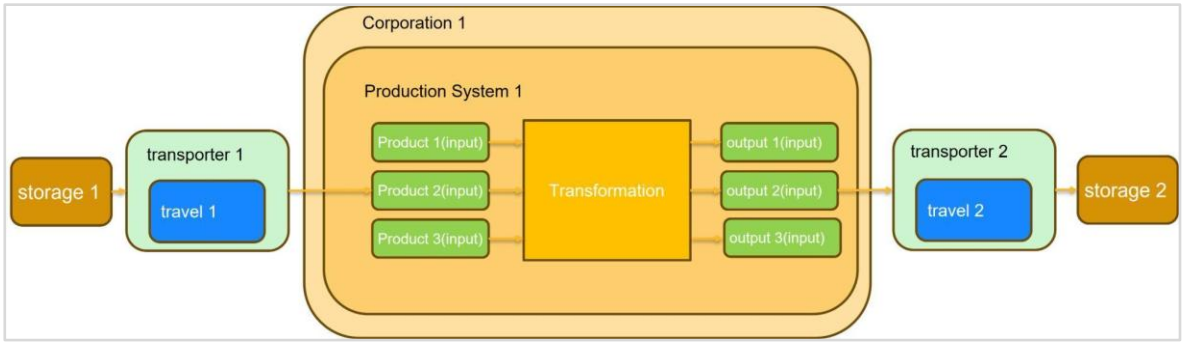


Figure 13. Example of basic template with predefined entities

This approach allows each box to trigger a form upon clicking, enabling users to input the corresponding fields easily, maintaining a clear overview of the entire process at all times.

In fact, the colour of each box could indicate whether a section is incomplete or contains an error, providing visual feedback to guide the user.

4.1.2 Bio-based industry

The following report summarizes the user experience gathered during a complete test of the BIT, carried out by creating a new user (CAP Holding SpA) with a Bioindustry profile and uploading a sample value chain (from the producer to the first buyer). The product generated for this value chain is a fertilizer obtained from the treatment of sewage sludge using lime and sulfuric acid "Gesso di defecazione (fertilizer)". It complies with the requirements of the Italian Legislative Decree 75/2010, which defines fertilizers within the national legislation.

Overall, the BIT UI is highly accessible and visually appealing. However, the user experience reveals some key areas for improvement, particularly within the administration interface (Twin·Picks), concerning clarity in the product creation workflow and the specificity of data input requirements. It is worth noting that the administration interface is more oriented toward technical users and is where the product creation workflow is carried out.

In this context, the initial use highlights that the BIT is not entirely intuitive, especially during the product creation process. The sequence of steps required to define a product is not clearly signposted, which impacts user efficiency.

A primary hurdle encountered was the language barrier, specifically the presence of French text in some sections. Furthermore, the absence of a visible, small language selection toggle (or dedicated page) on the interface makes language switching difficult, impacting usability for non-French speakers.

Defining the value chain components requires users to provide highly specific data, where clarity regarding definitions and units is essential.

4.1.2.1 Product Categorization and Definition

1. **Product Type Classification:** The prompt "What is the type of the product?" offers three options (Main Product, Residue or by-product, Raw material). To facilitate accurate classification, it is highly recommended to integrate a detailed information tooltip or pop-up pane. This should provide a brief description of each category, referencing relevant European regulatory definitions, as the distinction between "Residue" and "by-product" is often nuanced and critical for compliance.

2. **Units and Timeframe Ambiguity:** The input field "Specify the total amount or total weight (kg) in dry mass of the product" lacks crucial context.

    - It should be specified whether the required weight pertains to a single production batch, or if it is acceptable to input data on a monthly or annual basis. For certain industrial processes, such as Sewage Sludge treatment, monthly data is far more realistic and readily available.
    - It would also be beneficial to consistently request the total (wet) mass alongside the dry mass percentage for all materials, including raw materials, as this aligns better with common operational practices.

4.1.2.2 Sewage Sludge Specific Data

The data collection points specific to Sewage Sludge require refinement to align with typical Wastewater Treatment Plant (WWTP) reporting capabilities:

1. **COD Mass Input**: The question "(If Sewage Sludge) Specify the total amount or total weight of COD removed by the wastewater treatment process(es)... (in kg of dry mass)" is feasible, but the user notes that WWTPs can realistically provide this data only monthly, not per batch.

2. **Wastewater Volume Input**: The question "(If Sewage Sludge) Specify the total amount or total volume of wastewater treated... (in kg of dry mass)" contains two significant issues:

    - It is technically difficult to express the total volume of treated water in units of kg of dry mass. It is strongly suggested to request the volume in standard units L or m3, and use a separate parameter, such as Suspended Solids or COD/BOD load, to represent the mass component.
    - As with COD input, this data is readily available only on a monthly basis, not per product batch.
    - Furthermore, caution is advised as the total incoming dry mass to a WWTP (e.g., grit and stones) may not entirely contribute to the final sludge product, making this specific input potentially misleading.

4.1.2.3 System Functionality and Integration

1. **BioReCer Criteria Input**: The mechanism for entering BioReCer criteria is currently unintuitive. Implementing a simpler checkbox system ("Flushing") to flag compliance or non-compliance status would significantly streamline data entry.

2. **Saving and Progression**: The function of the "Provision ready" button is ambiguous. It is not clearly communicated to the user that this button serves as the final save and commit action after data upload is complete.

3. **Inter-Platform Progression**: Upon completing the product profile, the path to the subsequent BIT is unclear. The created product profile could not be located or imported into the next phase, indicating a potential break in the workflow continuity. This issue appears to stem from the requirement to define more than a single storage point; progression and visualization of the product's path were only enabled after creating a second storage point (the product's destination). To resolve this, implementing a 'hint' or 'guidance prompt' that explicitly suggests creating a second storage point would significantly improve workflow clarity.

4. **BitAdvisor Tool Usability**: While the BitAdvisor features attractive graphics and is easy to complete, its lack of a "back" or "undo" button for question responses is cumbersome. If a user makes an error, they are currently forced to restart the entire test.

4.1.2.4 Circularity indicator calculation limitations

During the testing of one of the bioindustry case studies (Italian case study), a few structural limitations became evident in the calculation of the CIs, particularly for

intermediate and final products in complex biorefinery processes. These constraints relate to the underlying calculation model rather than to user input.

A first limitation concerns the number of feedstocks that can be included in a single transformation. The CI calculation currently processes only up to six feedstocks for intermediate or final producers. In the Italian case, the relevant transformation involves eighteen inputs, meaning the computed CI reflects only a portion of the actual material flows.

A second limitation, which is more significant than the previous one, appears when the same product is listed as both input and output in a single transformation (e.g., AD or fermentation supernatants reused internally). The current CI formulation cannot resolve such loop configurations, which create circular dependencies. These cases require modelling the flows as separate batches or allocating them to distinct transformations.

These limitations do not compromise the BIT but reflect its current development stage. They also show that highly complex industrial value chains may exceed the present modelling capacity, offering useful guidance for future improvements of the BIT.

4.1.2.5 Recommendations

The primary suggestions derived from this user test are:

- **Improve Clarity and Guidance:** Implement clear, concise tooltips and formal definitions (referencing EU standards) for ambiguous terms like "Product Type."
- **Standardize Data Input:** Specify the accepted timeframe (monthly/annual vs. batch) for mass/volume inputs and ensure unit consistency (e.g., volume in m3, not kg dry mass).
- **Enhance Workflow:** Repair non-functional elements (language selector, glocalization) and clarify the product saving and transfer mechanism between the Twin·Picks and the BIT UI.

Addressing these points will significantly improve the platform's reliability for technical users and enhance its effectiveness as a project output.

4.1.3 Certifier

The following observations highlight areas where the certifier profile experience could be refined to better align with the role and needs of certification bodies:

- When a new user selects the "Certifier" profile type, a pop-up window appears prompting the registration of a company. While this step fits other user types, it may not be fully aligned with the certifier's role. Currently, the pop-up does not include options for certification bodies. Although there is an option to skip this step, it might be worth considering whether this pop-up could be omitted entirely for certifier profiles.
- After registration, the certifier is directed to the "Certification Schemes" tab. To enhance clarity and user engagement, this section could benefit from a brief header or guiding question. For example: “Looking for documentation on biobased certification schemes?”.

- The "Company Scores" tab offers a clean and intuitive overview of all companies and their scores. However, the following upgrades could be considered:
    - **Filtering Options**: Allow CBs to filter companies based on whether they are actively seeking an audit (information already collected during company registration).
    - **Certificate Visibility**: Display the sustainability certificates held by each company to support preliminary assessments.
    - **Contact Functionality**: Introduce a button enabling CBs to initiate contact with companies directly through the platform.
    - **Information Sharing**: Upon company approval (e.g., after signing a confidentiality agreement), additional registered data could be made accessible to CBs to facilitate audit preparation.

Also, in order to help facilitate communication, the tool could have a dedicated certification body's profile page available to industry companies where they could find contact information, as well as which certification schemes, they are accredited by. That would greatly help to know who's the most relevant CB to contact.

4.2 External validation

This section presents, on the one hand, the stakeholder events held in the three participating countries, Greece, Spain, and Italy, with the aim of obtaining external validation of the tool. It describes the methodology applied in the events, including their preparation and execution, and summarizes the results obtained for each use case, incorporating the feedback provided by the participants. Additionally, it presents the exploitation of the BIT by biomass associations, which is aligned with KPI 21.

4.2.1 General principles for Stakeholders Events

4.2.1.1 Users' participation & Iterative feedback loops

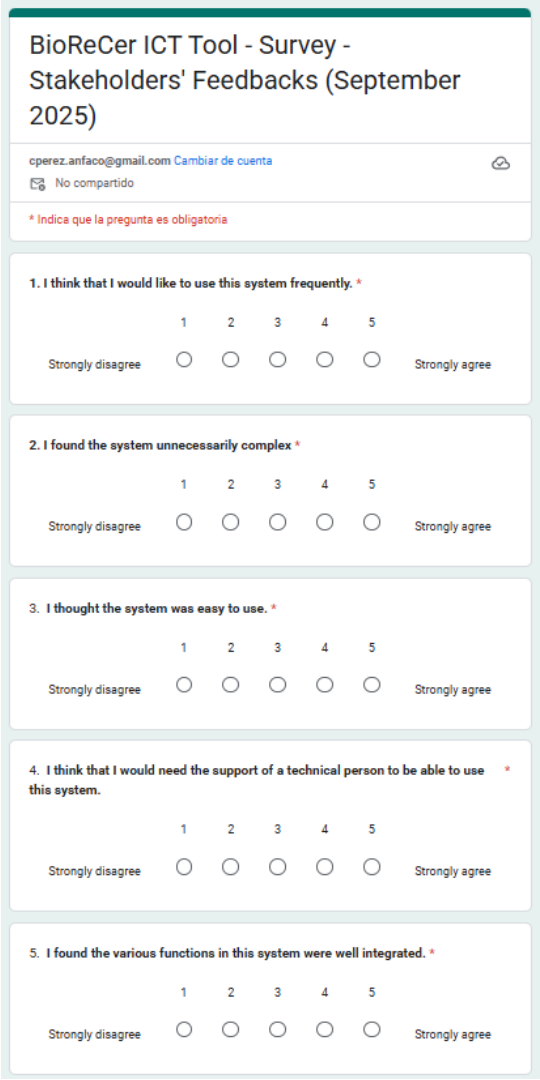
Stakeholder events have been effectively used to disseminate both the project and the BIT. Moreover, these events provided an ideal opportunity to test the tool and gather quick feedback from participants. Prior to each stakeholder event in the respective countries, targeted dissemination activities were carried out to engage companies and encourage them to learn about and test the application. To facilitate fast feedback during the events, short questionnaires were distributed at different moments throughout the sessions, allowing for efficient collection of user impressions and suggestions, as well as a standardized questionnaire to collect participants' impressions in a consistent manner.

4.2.1.2 Satisfaction criteria

Each stakeholder event was prepared using the similar methodology; however, the way it was executed varied across locations. As a result, it became necessary to standardize the evaluation process to consistently assess user satisfaction. For this reason, a standardized questionnaire was created to collect feedback in a uniform and comparable way across all

events, based on the System Usability Scale (SUS). The SUS survey was administered during the events held in Greece and Italy, whereas in Galicia it was sent to participants after the event, together with the presentation and the BIT manual translated into Spanish. In the specific case of the Galicia workshop, short questionnaires were employed, as described later, and distributed throughout the event in accordance with its dynamics and the tool demonstrations, with the aim of providing a more interactive and user-friendly experience.

The main objective of this SUS questionnaire is to collect feedback from participants regarding their experience with the BIT during stakeholder events or after using the tool, through a few short questions and a general comments section. It aims to evaluate the usability, usefulness, and overall impact of the tool, while also identifying areas for improvement based on user input.


BioReCer ICT Tool - Survey - Stakeholders' Feedbacks (September 2025)

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No compartido

* Indica que la pregunta es obligatoria

1. I think that I would like to use this system frequently. *

1 2 3 4 5

Strongly disagree ○ ○ ○ ○ ○ Strongly agree

2. I found the system unnecessarily complex *

1 2 3 4 5

Strongly disagree ○ ○ ○ ○ ○ Strongly agree

3. I thought the system was easy to use. *

1 2 3 4 5

Strongly disagree ○ ○ ○ ○ ○ Strongly agree

4. I think that I would need the support of a technical person to be able to use this system. *

1 2 3 4 5

Strongly disagree ○ ○ ○ ○ ○ Strongly agree

5. I found the various functions in this system were well integrated. *

1 2 3 4 5

Strongly disagree ○ ○ ○ ○ ○ Strongly agree

Figure 14. Screenshot of the standardized SUS questionnaire

4.2.2 Stakeholders events

The following sections present the three organized events, outlining the tasks carried out for their preparation and execution, as well as the results gathered through the questionnaires provided to participants and the impressions they shared with us during the events.

4.2.2.1 The fishery use case test in Galicia - Spain

In order to collect feedback from stakeholders in Spain, a specific workshop focused on the fishery use case was held at ANFACO-CEC`s headquarters, thereby contributing to the external validation of the tool based on this test conducted in Galicia (Vigo).

- **Preparation**

This Workshop for stakeholders in Spain was held on October 3, 2025, and the agenda was as follows:

- Attendee welcome
- Presentation of the project and its main results
- Presentation of the BIT:
  - General case based on BIT manual and videos
  - Specific Use Case of tuna cooking process
- Surveys for collecting feedback from attendees throughout the meeting
- Networking Coffee break at the end of the event.

The event was held in hybrid format to facilitate participant attendance, both in person at ANFACO-CEC`s headquarters and online via Zoom platform.

The ANFACO-CEC staff contacted potential stakeholders interested from different sectors such as Seafood Processing industry, Seaweed or Technology Developer to invite them to attend the event. Additionally, ANFACO-CEC's social media channels were used to increase the event's visibility, the posts are shown in Figure 15.

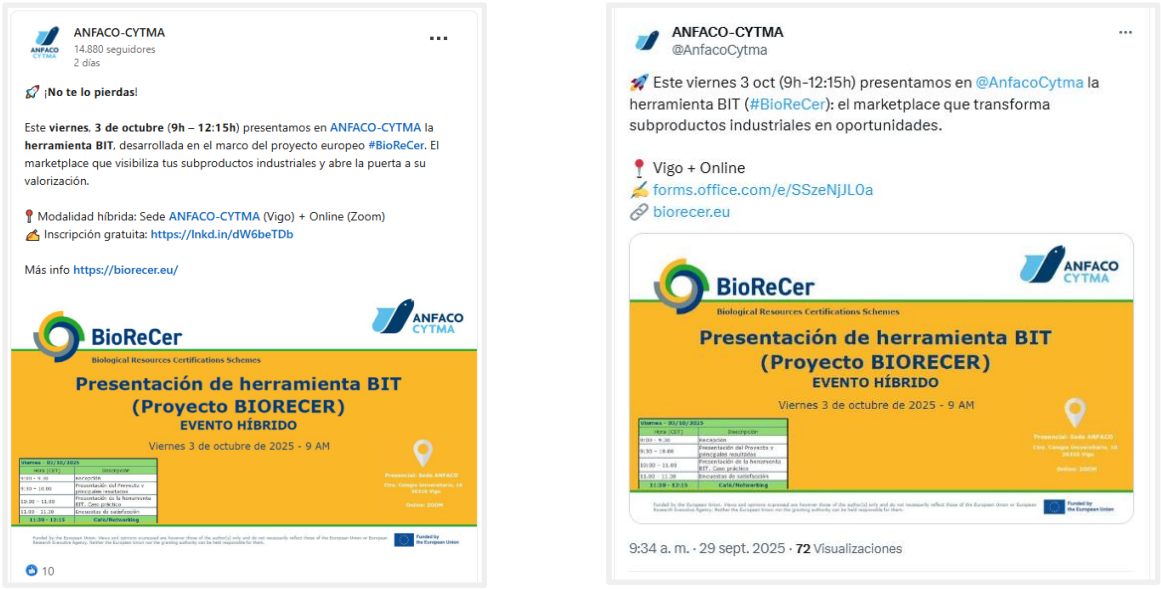

Figure 15. Workshop posts on ANFACO-CEC´s social media

- **Collected Feedback from Attendees**

Three short questionnaires were provided to the participants during the Workshop in order to collect their feedback. These questionnaires were provided at different times during the meeting according to its progress: after the Presentation of BioReCer project, after the general case and the last one after the Galician Use Case.

Different types of question formats were used in these surveys, depending on the scope and nature of each question, such as: Yes/No Questions; Rating Scale Questions; Multiple Choice Questions and Open-Ended Questions.

In this way, the first questionnaire titled "¿QUÉ OPINAS? Bloque inicial" (What do you think? Initial block) was presented after the Presentation of BioReCer and its main results in order to know the current status of each company in terms of the types of waste generated, validations or treatment of that waste and its current interest in valorising its biomass (Figure 16). The selected questions were the following:

- What type of waste does your company or activity generate? (Open-Ended Question)
- Are you currently carrying out any kind of recovery or treatment of that waste? (Yes/No Question)
- Would you be interested in recovering value from those biomasses? (Yes/No Question)

Figure 16. First questionnaire used in Vigo's workshop

The second questionnaire titled "¿QUÉ OPINAS? Bloque intermedio" (What do you think? Middle block) was presented after the General case use in order to know the attendee's perception about the tool and its functionalities, and its potential applicability to their current process (Figure 17). The chosen questions were the following:

- Did you find the platform intuitive to use? (*Rating Scale Question*)
- Do you consider the available functionalities to be useful? (*Rating Scale Question*)
- Do you consider it feasible to integrate this platform into your current processes? (*Rating Scale Question*)

Figure 17. Middle questionnaire used in Vigo's workshop

And the last questionnaire titled "¿QUÉ OPINAS? Bloque final" (What do you think? Final block) was presented after the Specific Use Case of tuna cooking process aimed to gather stakeholders` insights on how the tool could support the identification of new opportunities, what potential barriers they perceive could affect the adoption of the tool, and the willingness of stakeholders to integrate their value chains into the tool (Figure 18). The selected questions for this questionnaire were the following:

- Do you believe this platform could help you identify new opportunities for valorisation? (*Rating Scale Question*)
- Do you consider that it could facilitate regulatory compliance or the achievement of certifications? (*Rating Scale Question*)
- What barriers do you think might hinder the adoption of this tool? (*Multiple Choice Question*)
  - Lack of training
  - Compatibility issues with existing systems
  - Lack of knowledge about biomass valorisation
  - Associated costs
  - Lack of time or human resources
  - Resistance to change
  - Low volume of biomass generated
  - Unfavourable regulatory framework
- Would you be willing to input your value chains into the tool? (*Yes/No Question*)

- What additional functionalities would you like to see in future versions? (*Open-Ended Question*)

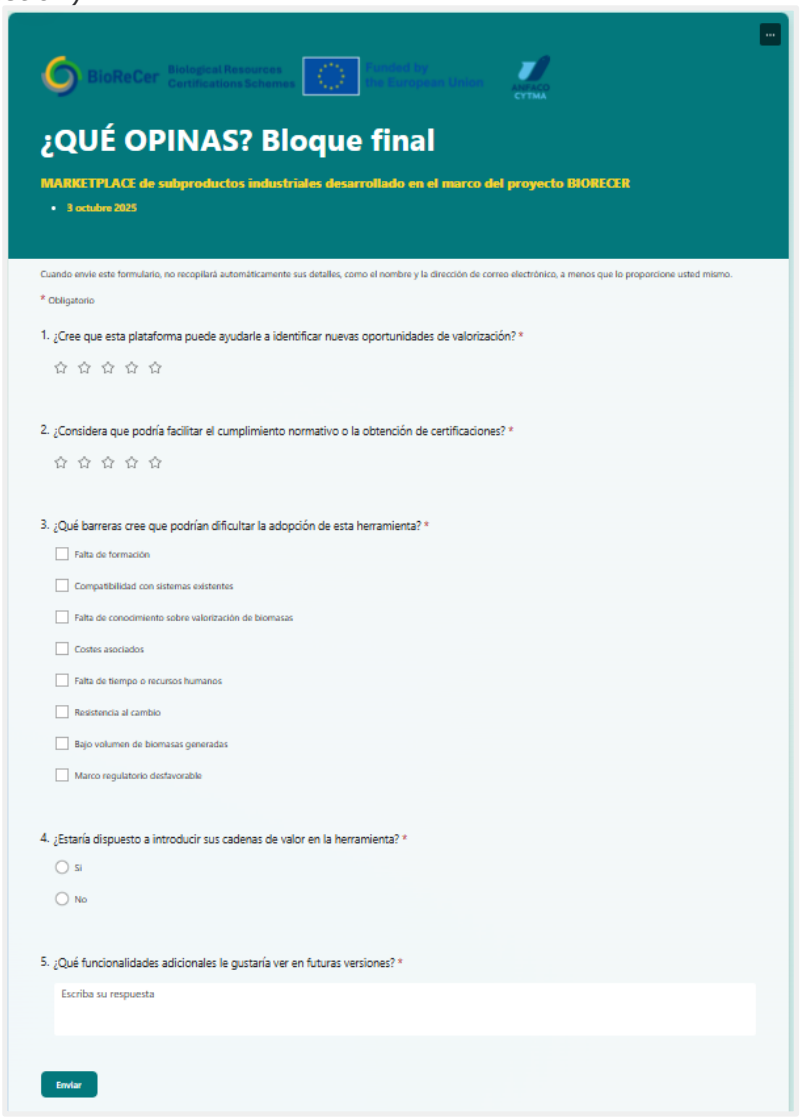

Figure 18. Last questionnaire used in Vigo's workshop

- **Event Execution**

As previously mentioned, the event was structured into three main blocks, followed by a networking coffee break:

  - Presentation of the project BioReCer and its main results
  - Presentation of BIT: General case based on BIT manual and videos
  - Presentation of BIT: Specific Use Case of Tuna Cooking Process

And the questionnaires previously mentioned were incorporated after each block in order to, on one hand, understand the current situation of the attendees regarding their waste management practices and interest in biomass valorisation, and on the other hand, to gather participants' impressions of the tool presented.
The event was attended by 17 participants, 7 were present on-site and 10 joined online and all of them showed great interest and active participation.

Attendees were welcomed at ANFACO-CEC`s headquarters by staff members from ANFACO-CEC and CETAQUA, representing the BioReCer team. The participants came from canning companies, producers, valorisation firms, associations, and technology developers. This diversity of participants enabled a broad exchange of perspectives to assess and share their impressions of the tool.

- **Presentation of the project BioReCer and its main results**

During this section of the presentation, the BioReCer project was introduced, highlighting its main objective and providing context regarding the current use of biomass. It was noted that biomass is increasingly seen as a valuable resource, although its integration into industrial processes still faces several challenges.

The role of BioReCer was presented as a contributor in the transition towards a circular economy. The project aims to demonstrate how innovative approaches can enhance the valorisation of biomass, reduce environmental impact, and foster resource efficiency.

Finally, the expected benefits of the project were mentioned, focusing on its potential to support more sustainable production models and promote innovation in the bioeconomy sector.

The first questionnaire was provided after this presentation in order to identify the types of biomasses generated by the participant's companies, the current valorisation practices, and their interest in biomass valorisation.

- **Presentation of BIT: General case based on BIT manual and videos**

In the section dedicated to presenting the BIT, the content was supported by the videos prepared by EGM. First, the registration process for the application was shown. Then, the BitAdvisor section was introduced, where companies can complete self-assessment questionnaires on Primary and Advanced requirements in order to obtain their scores and recommendations. After that, the sludge value chain, already available on the platform, was presented. Finally, the section of the tool related to Certification where a current overview of certifications potentially applicable to their by-products was introduced.

The second questionnaire was introduced at that point to assess how intuitive the tool appeared to the participants, how useful they found its functionalities, and finally, whether they considered the tool viable for use in their current processes.

- **Presentation of BIT: Specific Use Case of Tuna Cooking Process**

In the third and last section of the workshop a live demonstration was carried out showing how to input a value chain related to a Tuna Cooking Process, typically found in a canning facility.

After that section, the last questionnaire was provided in order to gather user feedback on the BIT. It asks whether the platform could help identify new opportunities, facilitate regulatory compliance or certification processes, and gathers insights into potential barriers to adoption. Additionally, it seeks to understand users' willingness to contribute their value chains and invites suggestions for future functionalities to enhance the platform's usefulness.

In addition, the event was promoted on ANFACO-CEC's social media a few days later, enhancing the project's visibility (Figure 19).

Figure 19. Workshop posts after the event on ANFACO-CEC´s social media

- **Post-event documentation**

After the event, participants received a follow-up email from ANFACO-CEC thanking them for their contributions and for the insightful feedback shared, where the presentation materials, the BIT user manual translated into Spanish, a link to access the BIT and the standardized SUS questionnaire were provided. This allows them to share their impressions and experiences after using the platform, helping us improve its usability and effectiveness. The results are presented in next section.

- **Results**

This section documents both the results collected during the workshop through the three short questionnaires provided, as well as the feedback from the SUS survey, which was

shared with stakeholders after the workshop along with event-related information via email.

Results of the three short questionnaires displayed during the workshop

The results of the three short questionnaires were displayed to participants in real time during the workshop as the responses were being collected. All the responses are summarized in the following paragraphs.

First of all, it is worth noting the sectors represented and their respective percentages are presented in Figure 20.

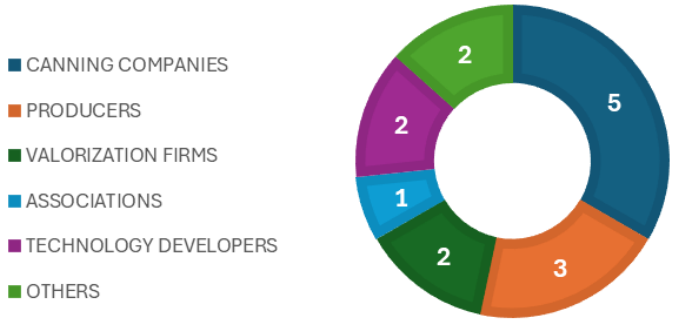

Figure 20. Participants by sector

Results of the first questionnaire titled "¿QUÉ OPINAS? Bloque inicial"

60% of participants reported fishery by-products as waste. Packaging materials, wood, oil, and similar items were grouped into a separate category, representing 40%. The wastewater and sludge were noted by 20% of the participants (Figure 21).

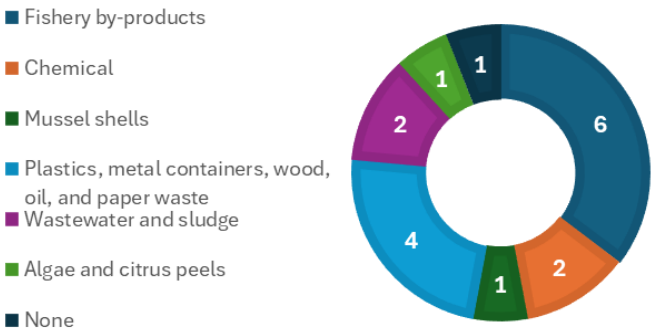

Figure 21. Types of waste produced by the participants

Regarding whether they carry out any valorisation process, 50% responded positively.

And finally, with respect to implementing valorisation processes, 9 out of 10 are interested. The one who was not interested explained that it was because they are a technology developer.

Results of the middle questionnaire titled "¿QUÉ OPINAS? Bloque intermedio"

Concerning the questions of the middle questionnaire they rated the tool 4.5 out of 5 based on how intuitive it appeared to them, 4.5 out of 5 regarding the usefulness of its functionalities, and 3.83 out of 5 when asked whether they considered the tool viable for use in their current processes, as shown in Figure 22.

Figure 22. The ratings given to the questions in the middle questionnaire

Results of the last questionnaire titled "¿QUÉ OPINAS? Bloque final"

Finally, this section presents the results of the final questionnaire. The participants rated 4.73 out of 5 regarding the tool could help identify new opportunities, and 4.36 out of 5 with respect to facilitating regulatory compliance or certification processes.

Concerning the potential barriers to adoption, 36% of participants believe it would be the lack of training, 54% point to compatibility with existing system, 27% due to lack of knowledge about biomass valorisation, only 9% reflect the associated costs, 45% related to lack of time or human resources, and 27% value both resistances to change, low volume of biomass generated and unfavourable regulatory framework. Conversely, 10 out of 11 participants expressed willingness to share their value chains.

As a final point, regarding the suggestions for future functionalities the respondents shared the followings:

- Facilitate data entry to reduce time.
- Integration with sensors (energy, water, computer vision) to automate data capture.
- Integration with existing systems such as ERPs, such an API that integrates with exciting systems. This would result in a system that is almost transparent to the user and with less resistance to change.
- A more intuitive tool.
- More connection between companies that contribute parts of the same value chain within the tool.
- Automation of the process of linking entities to make it more fluid, dynamic, and simple.
- Include an estimate of the carbon footprint resulting from biomass valorisation through added value and emission reduction data.

- **Final feedback round**

At the end of the presentations, a discussion session was opened where participants shared their impressions of the tool, the difficulties they encountered, and the functionalities that could improve its usability or make it more intuitive. Some of these opinions had already been included in the final questionnaire.

Certification process in the tool

In this feedback space, firstly questions were raised regarding certification within the tool. It was clarified that, although the certification process is external to the tool, the certifying entity can access it. In fact, this role is explicitly considered in the tool's functional design. Additionally, the data obtained during the certification process are taken into account when specifying the entities within the tool.

Tool Language

Participants also asked whether the tool translates the input data into another language, given that the available examples are in English while the session was conducted in Spanish. It was clarified that the tool does not perform translations; the data appear in the language in which they were entered. Although the expected area of influence for the valorisation of these biomasses usually does not involve cross-border transport—which entails a more complex regulatory framework.

Connection between companies that contribute parts of the same value chain within the tool.

Regarding the input of data from the various parts of the value chain and the connections between its different links, several uncertainties arise. Participants express concerns about how they can enter data related to segments of the value chain they are unfamiliar with—particularly those that fall under the responsibility of the next actor in the chain. This is perceived as a weakness of the tool.

It is noted that, in the demos, the entire value chain was entered into the tool, with all data linked, in order to demonstrate its potential. However, in practice, each company—each link in the chain—would only input the data relevant to its role. Currently, the tool's TRL is not yet at a level that allows for market deployment. Nevertheless, its potential lies in enabling each company to input the portion of the value chain it is responsible for. In fact, the tool is structured so that circularity indicators are generated in a cascading manner, which requires each actor to enter their data and to receive data from the preceding link in the chain.

In this context, it is suggested that the valorisation company, as the final link in the chain, could take the lead in configuring the entire value chain and assist the other stakeholders in entering data into the tool, given that it holds the knowledge about the requirements the biomass must meet.

Integration with existing systems in the companies

In line with what some participants also shared in the suggestions section of the questionnaire, a question was raised about whether the option of developing an API to automatically integrate data from existing factory systems, such as ERPs, has been considered.

It was explained that the way the platform has been developed makes it fully automatable and connectable, allowing for straightforward integration with the company's existing systems. In fact, the more automated the company is, the fewer data entries need to be manually uploaded, which in turn enhances traceability and demonstrates the full potential of the tool.

Moreover, although companies must undergo an audit to obtain certification, the auditing process benefits significantly when data input is carried out in a more automated manner.

Barriers to adoption

The responses collected in the latest questionnaire regarding barriers to adoption are being discussed in group. Some concerns have already been clarified through previous discussions.

Regarding the concern about the "Low volume of biomass generated" it has been clarified that this is not relevant because the tool is designed to be independent of the amount of biomass introduced. The main objective is to foster a collaborative ecosystem among stakeholders, and a high volume is not always necessary for the initiative to be valuable.

As for the potential barrier related to the regulatory framework, it has been clarified that this type of project is developed in alignment with existing regulations.

- **Results of the standardised SUS questionnaire shared after the workshop**

The questionnaire consisted of ten Likert-scale questions aimed at evaluating stakeholders' perceptions and their level of agreement with given statements. This survey was also shared during the Greek and Italian stakeholders events. A summary of the responses of Spanish stakeholders to the ten Likert-scale questions is provided in Table 2.

Table 2. Results of the Linkert-scale questions of the Spanish stakeholders collected after the workshop.

Question	Score
1. I think that I would like to use this system frequently.	3.6
2. I found the system unnecessarily complex	2.4
3. I thought the system was easy to use.	3.8
4. I think that I would need the support of a technical person to be able to use this system.	3.0
5. I found the various functions in this system were well integrated.	4.0
6. I thought there was too much inconsistency in this system.	2.2
7. I would imagine that most people would learn to use this system very quickly.	4.2
8. I found the system very cumbersome to use.	2.8

Question	Score
9. I felt very confident using the system.	3.6
10. I needed to learn a lot of things before I could get going with this system.	1.8

4.2.2.2 The agriculture use case test in Greece

The external validation of the agricultural case study focused on the Region of Central Macedonia in Greece has been conducted through the final Greek stakeholders' workshop. The preparation steps, execution and outcomes of the event are presented in the following sections.

- **Preparation**

The final Greek stakeholders' workshop was held on October 8, 2025, and was an online event via the Webex platform. Prior to the event, CERTH partners sent an informational email to the potential stakeholders, kindly inviting them to virtually attend the event, acknowledging their valuable contribution throughout the BioReCer Project. In this context, the Webex link and event agenda was also shared, which included:

- Attendee welcome (Dr George Banias)
- Presentation of the project and its main results (Dr Sotiris Patsios)
- Integration of BioReCer framework into the existing biobased certification schemes (Ms Monica Pandey)
- Agricultural biomass as feedstock: the case of sustainable particle board production (Ms Maria Batsioula and Anthoula Karanasiou)
    - Results on life cycle assessment,
    - Results on the estimation of the circularity indicators
- BioReCer ICT tool (BIT) (Ms Stamatia Skoutida)
    - General presentation of the BIT
    - Case specific example on the straw-based particle board production
- Validation of the BIT | Q&A
- Closing of the event

To maximize attendance and increase the event's visibility, two LinkedIn posts have been prepared and posted on LinkedIn by the two CERTH laboratories participating in the BioReCer Project: the Laboratory of Environmental Engineering and Sustainability (Institute of Bio-economy and Agri-technology) and Natural Resources and Renewable Energies Laboratory (Chemical Process & Energy Resources Institute).

- **Event Execution**

Methodology

This online event was organized to present the results with a focus on the BIT through a structured series of presentations and acquire feedback through a questionnaire. The event

began with an overview of the project's outcomes, given that this was the final opportunity to engage with stakeholders who had been involved since the beginning of the project. Special emphasis was placed on the integration of the BioReCer framework into existing bio-based certification schemes, presented as a key project outcome. A complete agrifood value chain was used as the basis for the application of the Project's outcomes in a more comprehensive and stakeholder-relevant manner. Specifically, the conversion of straw into particle boards was selected as an illustrative example, which represents one of the main value chains in the agri-food sector studied within the Project and was of particular interest to the attendees. This value chain was used for demonstrating the outcomes of the sustainability and circularity assessments. Following, as the core of the event, the BIT was presented. The demonstration included an overview of the tool, objectives and functionalities. The practical demonstration was conducted through pre-recorded videos as well as live real-time interaction with the tool, by uploading data and validating the straw-based particle board value chain. Finally, participants were invited to complete a tailored questionnaire in order to provide their feedback on the tool. Throughout the event, sufficient time was foreseen for questions, remarks, and discussion to maximize stakeholder engagement and interaction. Valuable feedback and suggestions concerning the platform were received from the stakeholders, providing important input for its further improvement. Furthermore, an understanding of the stakeholders' perception of the project and its outcomes was gained.

Structure of the event

The event began with a warm welcome to all participants and stakeholders, expressing gratitude for their attendance and for their support throughout the three years of the BioReCer project. Emphasis was placed on the critical role of participants' contributions, suggestions, and feedback in ensuring the quality and proper evaluation of the project's outcomes.

Presentation of the Project and Its Main Results

The first presentation of the event provided a concise overview of the main results of the BioReCer project. Key achievements from the three-year implementation were highlighted, particularly those relevant to primary producers, industrial actors, certification bodies, and ultimately end consumers. The presentation covered the project's major findings, including insights into best practices for bio-based value chains, and underscored the practical significance of the results for both stakeholders and the broader bio-based sector.

Integration of BioReCer framework into the existing biobased certification schemes

In the following session, the BioReCer framework and its integration into existing bio-based certification schemes was presented with the support of MEO CARBON, emphasizing this as a key result of the project. The session outlined how the framework's indicators and criteria complement and enhance current certification schemes and highlighted their alignment with international practices. The discussion showcased how the framework supports sustainability, transparency, and traceability across bio-based value chains.

Agricultural biomass as feedstock: the case of sustainable particle board production

In this session, the presentation of sustainability assessment and circularity indicators of the BioReCer Project took place, explaining key concepts and providing insights for their estimation. Also, a practical case study in the Region of Central Macedonia was presented, examining the use of agricultural residues, specifically straw, for the production of particle boards.

- Results on Life Cycle Assessment (LCA): The LCA results were presented, demonstrating the environmental profile of straw-based particle boards in comparison to the conventional counterparts deriving from primary wood.
- Results on the Estimation of the Circularity Indicators: Results for circularity indicators were shared. The entire value chain of the product was covered, from biomass production, through industrial processing and ending in the use phase and the end-of-life options

BIT presentation

The BIT was introduced, covering both general concepts and the application in a specific case study, based on the particle board production. The session included videos demonstrating the platform's functionalities, as well as live real-time usage of the platform to provide a comprehensive and practical illustration. During the presentation, its capabilities for monitoring sustainability and circularity indicators, managing data, and supporting decision-making across bio-based value chains were emphasized. The presentation was structured in two pillars:

- **General Presentation of the BIT**: The session covered the tool's main features, including data input, monitoring of indicators, and report generation. The BIT was highlighted as a practical solution for decision support across all participants in bio-based value chains.
- **Case-Specific Example on the Straw-Based Particle Board Production**: A live demonstration was conducted using the straw-based particle board case study. This procedure showcased how the platform can be used to track environmental and circularity performance in real-world production, illustrating its practical application for stakeholders.

At the end of the presentations, a questionnaire was addressed to the stakeholders using Mentimeter, an online, freely available real-time audience interaction platform. The questionnaire included the questions suggested by EGM and ACN to collect feedback in a homogenized way addressing all the important aspects of the BIT. The questions have been translated to Greek in order to facilitate stakeholder understanding and engagement and are summarized below:

The first section included 10 questions to be responded with a Linkert scale 1-5 (1 corresponds to complete disagreement and 5 to complete agreement).

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.

9. I felt very confident using the system.

10. I needed to learn a lot of things before I could get going with this system.

The second section included three open-ended questions:

- What were you expecting to see and was missing in the application?
- If everything was technically possible, what would you like to be able to do with the tool?
- Anything else you would like to share?

Throughout the questionnaire session, adequate time was foreseen for the stakeholders to provide their answers, and all necessary explanations were given for each question. The questions were separated into five blocks to facilitate stakeholders' responses and initiate discussions. The results are presented in the following subsection.

Post-event interaction

After the event, a thank-you email was sent to all participants, expressing appreciation for their involvement and constructive feedback during the final online meeting of the final Greek stakeholders event. The email summarized the positive reception of the BIT and noted that participants' suggestions will be considered in its final development. Recipients were also invited to further test the tool by sharing the link, contact CERTH team for any question they may have and stay engaged with future BioReCer activities.

Additionally, a LinkedIn post that expresses our gratitude for participation summarizing the key outcomes of the event was uploaded on the account of the Laboratory of Environmental Engineering and Sustainability of CERTH (Figure 23).

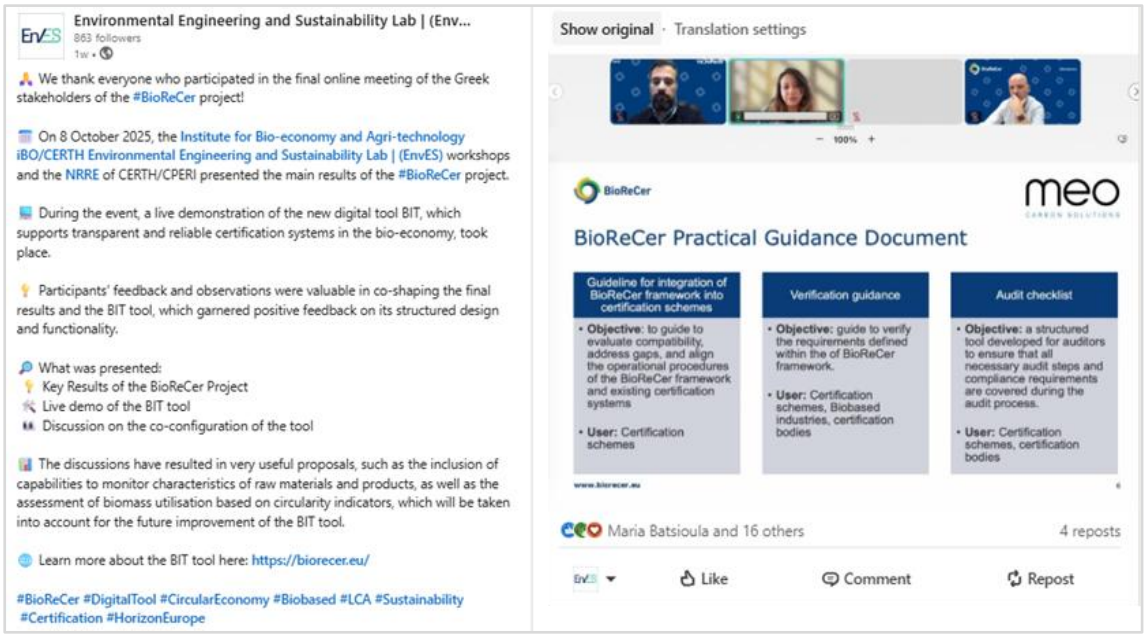

Figure 23. Post-event LinkedIn post for the Greek stakeholders event

- **Results**

In this section, the outcomes of the questionnaires are presented, along with insights and impressions collected from the participants during the event. A total of 21 stakeholders took part in the event, representing various fields of expertise. The sectors represented by the workshop participants are summarized in Figure 24.

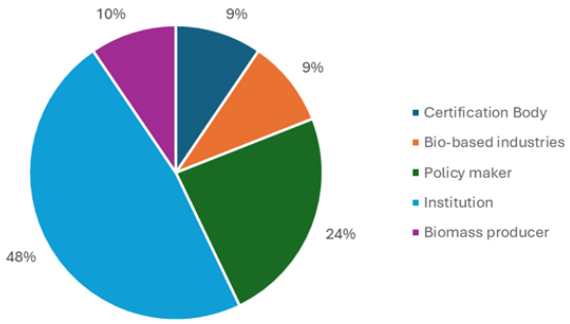

Figure 24. Participants by sector (Greek Stakeholder event)

The main outcomes of the Final Greek Stakeholder event concerned the questions addressed through the questionnaire focusing on the BIT. In total, 13 answers were collected through the questionnaire. The results of the ten Likert-scale questions are presented in Table 3 and the relevant snapshots of the Mentimeter platform are presented in Figure 25.

Table 3. Results of the Linkert-scale questions of the Greek stakeholder event.

Question	Score
1. I think that I would like to use this system frequently.	3.9
2. I found the system unnecessarily complex	2.1
3. I thought the system was easy to use.	3.8
4. I think that I would need the support of a technical person to be able to use this system.	2.5
5. I found the various functions in this system were well integrated.	4.2
6. I thought there was too much inconsistency in this system.	1.6
7. I would imagine that most people would learn to use this system very quickly.	3.6
8. I found the system very cumbersome to use.	2.2
9. I felt very confident using the system.	3.2
10. I needed to learn a lot of things before I could get going with this system.	3.1

Figure 25. Snapshots of the responses received through the Mentimeter platform

Summary of the findings

The meeting was considered successful, as positive feedback from stakeholders regarding the digital tool was received, with particular emphasis on its well-structured design and overall functionality. It was noted that a technical guide for tool completion and use would be highly valuable for users, in order to ensure a more efficient and standardized application. Although it was pointed out that a more thorough examination is needed to identify potential gaps, the tool appears informative and well-organized at first glance. Stakeholders also suggested that it would be beneficial for the tool to allow users to monitor specific characteristics of raw materials and final products, such as purity, moisture content, organic matter, and nutrient composition to assess their suitability for various applications. Furthermore, the tool could provide added value by enabling biomass producers to identify and explore potential valorisation pathways for their biomass, based on circularity indicators. This functionality would support decision-making, either for in-house utilization or for establishing partnerships with industries for further exploitation of the biomass. In this way, the tool could also be applicable and useful for public waste management organizations (e.g., FODSA). Finally, it was proposed that the tool could be linked to the Corporate Sustainability Reporting Directive (CSRD), allowing for the export of relevant data to support sustainability reporting processes.

4.2.2.3 The Urban bio-waste use case test in Italy

In order to collect feedback from stakeholders in Italy, SPRING, in collaboration with UNIVPM and Gruppo CAP, organized a workshop focused on the urban bio-waste use case in Rimini during Ecomondo, the leading annual event in the fields of green and circular economy. Ecomondo serves as a key meeting point for industries, stakeholders, policymakers, opinion leaders, researchers, and institutions, bringing together the main drivers that shape the European Union's environmental policy strategies. The decision to hold the workshop during the fair aimed to reach a broad and diverse range of stakeholders in the sector and to validate the BIT.

- **Preparation**

The stakeholder workshop in Italy was held in person in **Rimini** on **November 7, 2025**, and featured the following agenda:

- Welcome and introduction by the organizers
- Presentation of the project
- Contribution by UNI on the importance of standards in supporting the market uptake of bio-based products
- Main results of the project and validation in the Italian case study
- Demonstration of BIT through an interactive session including surveys and discussion:
    - General overview based on the BIT manual and tutorial videos
    - Specific application to the urban bio-waste use case

The workshop was promoted through Ecomondo's official channel[1] as well as SPRING's communication channels, with the support of local partners, particularly UNIVPM and CAP.

SPRING invited its internal network and other potential bio-industries interested in joining the event. The workshop has been shared through the institutional website, the LinkedIn channel and the newsletter in order to increase the event's visibility and to attract a broad range of interested stakeholders.

- **Event Execution**

The participants were welcomed by the organizers of the workshop: UNIVMP, Gruppo CAP and SPRING.

The event, held in Italian, started with a brief introduction by the organizers and the presentation of BioReCer project along with the main results achieved after 3 years.

UNI, as a project partner of BioReCer, delivered a focused presentation on the role of certification and standardization in supporting the development and market uptake of bio-based products.

[1] https://www.ecomondo.com/it/dettaglio-evento/BioReCer%20%20Innovazione%20tracciabilit%20e%20certificazione%20europea%20nel%20settore%20bio-based?eventId=4821481

The second part of the workshop was mainly dedicated to the Italian case study, featuring a detailed presentation and a live demonstration of the BIT conducted by Gruppo CAP. This session provided participants with a concrete example of how the tool can be applied to real-world scenarios.

After the presentation, an interactive session was held to gather participants' impressions and feedback on the tool. This stakeholder engagement activity was facilitated and moderated by SPRING, encouraging open discussion and exchange of ideas among the attendees.

Presentation of the BioReCer project

The initial presentation provided an overview of the project, outlining its overall framework, main objectives, and the outcomes. In addition, it highlighted the roles of UNIVPM, Gruppo CAP, and SPRING within the Italian case study, which focuses on biobased secondary raw materials derived from urban and industrial activities.

Intervention by UNI

The presentation, titled "A Strategic Standardisation Roadmap to Support the Market Uptake of Bio-based Products", explored how standardisation can act as a bridge between research and the market. During this session, UNI highlighted the crucial link between standardisation and research activities, showing how technology transfer and co-design processes help ensure that research outcomes are shared effectively with industry stakeholders and can be translated into concrete market solutions.

The contribution of UNI to the project was then presented in detail. This included conducting a comprehensive review of existing standards relevant to the project's scope, assessing the needs and analysing existing gaps in current standardisation frameworks. This work led to the development of the Open Standards Research Tool, a comprehensive guide to bio-based standards and certification schemes. Building on this foundation, UNI outlined the steps taken to formulate a strategic roadmap aimed at transferring the project's results to the market through targeted standardisation actions.

Presentation of the main results of the project and validation in the Italian case study

The presentation entitled "Application of the BioReCer Framework and LCA Evaluation: The Italian Case Study on Urban Wastewater Treatment and Non-Hazardous Special Waste" illustrated the work conducted within the Italian case study, detailing the activities carried out and the results of the validation of the framework, circularity indicators, and LCA, as reported in deliverable D6.2 Final Case studies report.

Presentation of the BIT: BIT manual, videos and Italian case study

The presentation focused on the live demonstration and functional capabilities of the BIT. The introductory section outlined how the digital platform is designed to support stakeholders in informed decision-making by providing an objective framework that maps relevant standards and certifications for bio-based products and identifies sustainable value chain actors.

The presentation detailed the BIT's architecture with the three core modules:

- BitAdvisor (Decision Support System - DSS)
- Product Search, enabling supply chain exploration, traceability, and access to a Digital Product Passport
- Certifications Module, addressing industry standards, sustainability scores of entities, and the "Looking for Audit" signal

The session also included videos prepared by EGM, guiding the audience through the onboarding process, the use of BitAdvisor, certification search functionalities, and data feeding. Conversely, the product functionalities were demonstrated interactively during the subsequent live session.

Following the structural overview, a live and interactive demonstration of the tool was conducted using the Italian Case Study on urban sewage sludge treatment as a practical example. This real-time demonstration showcased how the BIT manages and visualises key data points, including:

- Product geo-localization within the supply chain.
- The use of Blockchain technology to ensure secure and traceable tracking from the raw material origin (sewage sludge) to the intermediate product (PHA-rich sludge).
- Display of the Digital Product Passport, detailing the material transformation process.
- Visualisation of sustainability criteria associated with the resulting bioproducts.

This hands-on session served as an important step toward collecting feedback from stakeholders. It allowed for a direct technical assessment and validation of the tool's usability and functionality, informing future developments such as the integration of Artificial Intelligence (AI) features.

Interactive session

The last part of the workshop was dedicated to collecting feedback from participants on the BIT and addressing their questions.

The standardized questionnaire, prepared by EGM, was provided to participants to assess participants' satisfaction with the tool's usefulness and to gather valuable input for its further improvement. To ensure an engaging and interactive experience, responses were collected via the Mentimeter platform, which allowed participants to provide answers anonymously and view the results in real time. This approach encouraged immediate discussion and reflection among attendees. To validate the tool, the questionnaire was administered after the demonstration of the BIT and the presentation of the Italian case study, which served as a practical example of its application.

The questionnaire consisted of ten Likert-scale questions aimed at evaluating stakeholders' perceptions and their level of agreement with given statements. In addition, two open-ended questions were included to identify the perceived strengths of the tool and to collect suggestions on potential improvements aimed at enhancing its functionality, usability and overall effectiveness.

The activity was carried out collectively, with each question being read and briefly explained before giving participants sufficient time to provide their responses. The result of each question has been displayed and discussed in real time, fostering a constructive dialogue with the audience. The event concluded with a Q&A session, giving participants the opportunity to ask further questions and clarify any remaining doubts.

Post-event interaction

After the event, participants received follow-up email from SPRING thanking them for the contribution to the workshop and valuable feedback provided. The message included the BIT manual and a link to access the tool, encouraging further testing and exploration of its features. UNIVPM, SPRING and Gruppo CAP team also made themselves available to answer any additional questions or provide clarifications.

The main outcomes of the workshop were subsequently shared through SPRING's communication channels, including a dedicated LinkedIn post to further disseminate the results and maintain engagement with the stakeholders (Figure 26).

Figure 26. Post-event LinkedIn post for the Italian stakeholder event

- **Results**

This section presents the results of the questionnaire along with the main insights and key messages highlighted during the event.

The workshop was attended by 20 participants. Fourteen of them, representing a wide range of sectors, including biomass producers, industry associations, bio-based industry, public institutions, start-ups, SMEs, academia, and research organizations, took part in the final interactive questionnaire. Their distribution by stakeholder category is shown in Figure 27, while the results of the ten Likert-scale questions is provided in Table 4.

Figure 27. Participants by sector in the Italian stakeholder workshop

Table 4. Results of the Linkert-scale questions of the Italian stakeholder workshop.

Question	Score
1. I think that I would like to use this system frequently.	4.1
2. I found the system unnecessarily complex	1.8
3. I thought the system was easy to use.	3.6
4. I think that I would need the support of a technical person to be able to use this system.	2.2
5. I found the various functions in this system were well integrated.	3.9
6. I thought there was too much inconsistency in this system.	1.3
7. I would imagine that most people would learn to use this system very quickly.	4.2
8. I found the system very cumbersome to use.	2.4
9. I felt very confident using the system.	4.1
10. I needed to learn a lot of things before I could get going with this system.	2.6

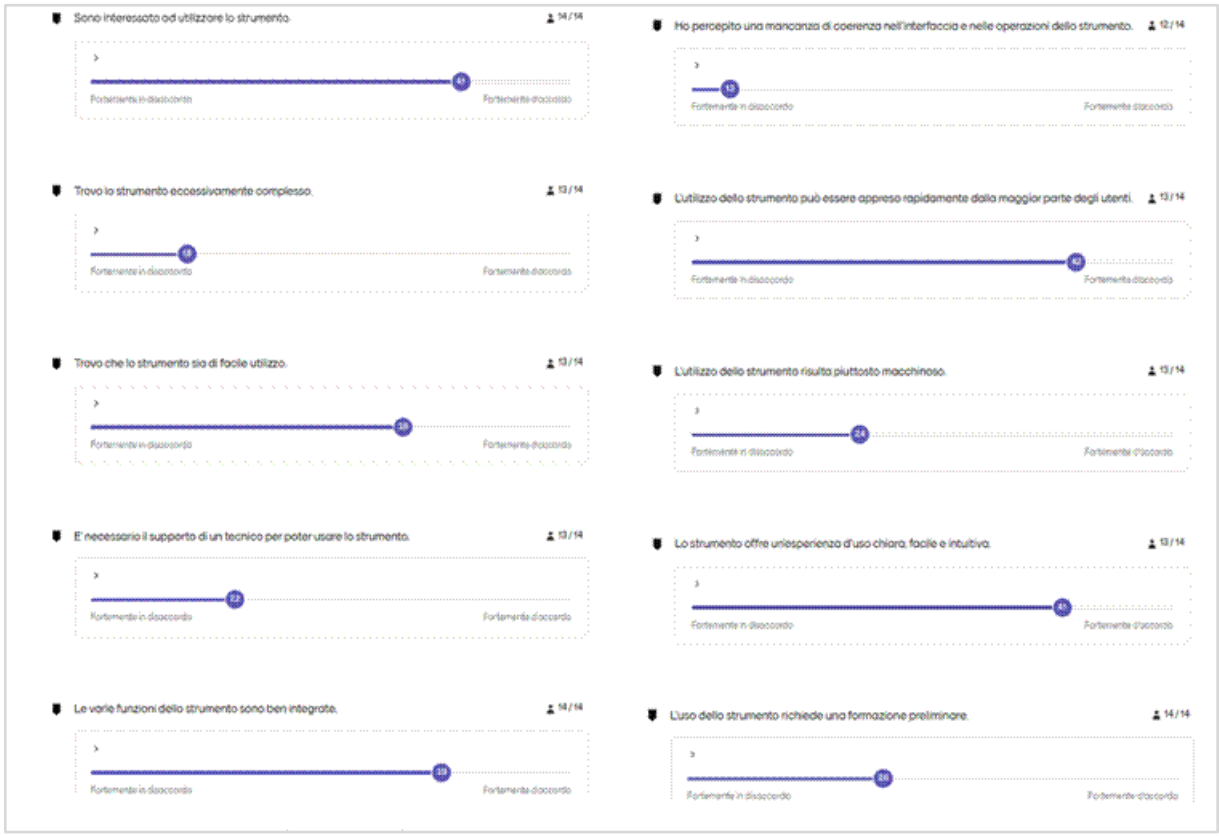

Figure 28. Snapshots of the responses on Mentimiter

Participants were also asked to rate the usefulness of the tool in its current version on a scale from 1 to 100. The average score was around 80.

The final part of the session focused on an open discussion aimed at identifying the tool's current strengths as well as missing or desirable features to be integrated in future versions. The results of this discussion are summarised in Table 5.

Table 5. Results of the open discussion on strengths and features to be implemented in the tool.

Strengths	Functionalities/Features to be implemented
Product traceability	Additional functions to search for customers, suppliers, and services, in addition to product searches
Digital product passport	Integration of a bot or AI assistant to guide users through the different steps of the tool
Recommendations on a company's eligibility for certification and on available pathways to achieve higher-level certifications	Inclusion of guidelines and suggestions directly within the tool to support data entry and use
Sustainability characteristics of the final product	Ability to link the impacts of the entire production process, not only transport, possibly with normalization (e.g., per kg or per m^3 of water)
Support for inexperienced companies and start-ups entering the bio-based certification landscape	
Search tool for bio-based standards and certifications	
Interaction between certification bodies and industries interested in certification and audit requirements	
Self-assessment mechanism for companies to understand their current status and identify areas and methods for improvement	
Integration of the entire value chain into a single platform, ensuring transparency on the origin of various products	

Summary of findings

The workshop was a success, providing valuable feedback from external stakeholders and confirming the positive reception of the BIT developed within the project in terms of both usefulness and functionality.

Responses to the ten survey questions, ranging from "strongly disagree" to "strongly agree," indicate that stakeholders generally perceived the tool as highly useful and expressed interest in using it. Most participants also found it easy to use and well-structured. Only a few reported that certain features were slightly complex or cumbersome,

suggesting that preliminary guidance or technical support could be beneficial for first-time users.

Overall, participants rated the tool's current usefulness at approximately 80%. Key strengths identified include its ability to ensure product traceability and provide a digital product passport, its support for inexperienced companies and start-ups entering the bio-based certification landscape, the opportunities it offers for interaction between certification bodies and industries, and the self-assessment feature that allows companies to evaluate their current status and identify areas for improvement.

At the same time, participants suggested several enhancements for future versions. These include enabling searches for customers, suppliers, and potential collaborators; integrating the existing user manual directly into the tool to guide users through all steps; and extending the ability to link environmental impacts to the entire production process—not just transportation—to increase the tool's relevance and practical value.

In summary, the feedback highlights the strong perceived value of the BIT, while providing clear directions for further development to make it even more user-friendly, comprehensive, and impactful for stakeholders across the bio-based sector.

4.2.3 Exploitation of the BIT by biomass association

This section addresses the actions carried out by the biomass producer association: ANFACO-CEC and the RISE PROCESSUM cluster, aligned with the fulfillment of KPI 21 described as "2 Biomass producers associations (ANFACO-CEC, PROCESSUM) exploit/use the new system".

4.2.3.1 Biomass producers association ANFACO-CEC

In May 2025, ANFACO-CEC distributed an informative circular to its network of associated companies and collaborators to announce the launch of the BIT and invite them to participate in the forthcoming validation activities. This action aimed to raise awareness of the BIT and encourage stakeholder engagement within the Galician seafood sector. Subsequently, as previously mentioned on October 3rd, ANFACO-CEC organised a stakeholder workshop in Vigo (Spain) focused on the fishery use case to validate the BIT in the regional context. The event, held in hybrid format, gathered 17 participants from different sectors, including canning industries, biomass valorisation companies, technology developers, and sectoral associations. During the session, the BIT was presented through a general demonstration and a specific case related to the tuna cooking process, representative of the regional seafood industry. Three short questionnaires were used to collect feedback on participants' waste valorisation practices, perceptions of the tool's usability and functionalities, and potential barriers to adoption. Overall, the feedback was highly positive: participants rated the tool's intuitiveness and usefulness above 4.5/5 and expressed strong interest (over 90%) in integrating their value chains into the platform. The main improvement suggestions focused on facilitating data input, improving compatibility with existing systems, and enhancing inter-company connections within the tool.

4.2.3.2 Exploitation to RISE PROCESSUMs cluster

On May 8th 2025, the BIT was presented at PROCESSUMs members meeting in Örnsköldsvik, Sweden, reaching a total of 37 potential stakeholders. They represented the forest industry, the chemical industry, technology providers, clean tech companies, representatives from collaboration platforms for business development and development projects, as well as the municipality and the region. On June 2nd 2025, RISE delivered an e-mail launching the BIT to 99 potential stakeholders within their cluster. 53% of the recipients opened that e-mail within 2 weeks. Among those 52 recipients who opened the e-mail, 23, i.e. 44.2%, clicked on at least one of the links within the e-mail. However, in line with previous outreach activities this did not result in an increased number of stakeholders or registered users of the BIT.

5 Conclusions

As mentioned above, the development of the BIT UI followed an iterative, user-centered design approach that prioritized usability, accessibility, and stakeholder engagement. Based on this premise, the BIT was designed with a mobile-first philosophy, recognizing the operational realities of bio-based supply chain stakeholders, which work in environments where mobile devices represent the primary or sole means of digital access.

Its validation has been carried out from two perspectives: an internal validation performed by the project partners and an external validation through stakeholder events where the tool was presented and their feedback collected.

Regarding internal validation, the project partners conducted it under the three key roles of biomass producer, bioindustry, and certifier. The main conclusions drawn are:

The initial company and user registration process is well-designed, and the user experience with the BitAdvisor section, the visualisation interface for exploring by-products and value chains, is friendly and intuitive, presenting itself as a visually appealing and easily accessible instrument.

In relation to the Digital Product Passport, along with data on emissions and analytical parameters, it is well-structured and clearly presented, allowing for efficient access and interpretation.

Some key areas for improvement concern clarity in the product creation workflow and the specificity of data input requirements, as well as limitations related to CI calculations for highly complex industrial value chains.

Although the administration interface, Twin·Picks, makes complex data management tasks accessible through guided workflows and intuitive interfaces, it is not as intuitive or user-friendly as the visualisation interface, BIT UI, it is more oriented toward technical users. This makes uploading a new value chain into the tool likely the most complex task, requiring more user input and attention compared to other features.

To mitigate these difficulties, comprehensive user documentation has been developed to support administrators and data providers, titled the BIT Manual, which includes detailed guidance on data provisioning, access management, and other administrative tasks. Additionally, contextual help within the interface provides just-in-time guidance for specific tasks.

Future improvements identified include enabling the interface to provide various templates with predefined entities to facilitate efficient loading and organization of value chains.

Regarding external validation, feedback was received from different stakeholder sectors, such as biomass producers, bio-based industries, certification bodies, policymakers, technology developers, associations.

The positive reception of the BIT developed within the project is noteworthy in terms of both usefulness and functionality, with particular emphasis on its well-structured design and overall functionality.

The tool's capability for evaluating certification readiness was highly valued; in fact, it could help stakeholders identify gaps in their sustainability practices before engaging with certification bodies, potentially reducing audit costs and preparation time.

Another well-appreciated feature is the automatic calculation and display of circularity indicators for stakeholders interested in demonstrating the circular economy credentials of their products. However, clearer explanations of how indicators are calculated would be beneficial, such as adding contextual help and/or benchmark comparisons.

Certain features were found slightly complex or cumbersome by some participants, suggesting that preliminary guidance or technical support could be beneficial for first-time users. They indicated that a technical guide for platform completion and use would be highly valuable to ensure a more efficient and standardized application. Thus, the BIT Manual was developed and shared.

The administration interface, Twin·Picks, was perceived as more difficult and less user-friendly than the visualisation interface, BIT UI. However, the tool has been developed to be fully automatable and connectable, allowing for straightforward integration with the company's existing systems. Therefore, the more automated the company is, the fewer data entries need to be manually uploaded.

Stakeholders proposed for future versions:

- Enabling searches for customers, suppliers, and potential collaborators.
- Integrating the existing user manual directly into the tool to guide users through all steps.
- Allowing users to monitor specific characteristics of raw materials and final products, such as purity, moisture content, organic matter, and nutrient composition, to assess their suitability for various applications.

6 List of abbreviations

BIT	BioReCer ICT Tool
BIT UI	BioReCer ICT Tool User Interface
CI/CD	Continuous development and integration
CI	Circularity indicators
DID	Decentralized Identifiers
DNSH	Do No Significant Harm
DPP	Digital Product Passport
DSS	Decision Support System
GDPR	General Data Protection Regulation
GHG	Greenhouse Gases
HSI	Hyperspectral Imaging
ISCC	International Sustainability and Carbon Certification
LCA	Life Cycle Assessment
NGSI-LD	Next Generation Service Interfaces for Linked Data
PEB	Project Executive Board
T&T	Track and Traceability

7 References

[1] EGM - BioReCer ICT Tool (BIT) Manual. Available online: https://biorecer.eu/biorecer-ict-tool-bit/ (accessed on 28 November 2025).