WOOD2WOOD

A Wood-to-Wood Cascade Upcycling Valorisation Approach

» Deliverable 13.5

Integrated Circular Wood Upcycling Platform (version 1)

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PU	Public	X
RE	Restricted to a group specified by the consortium	
CO	Confidential, only for members of the consortium (including the European Commission Services)	

Legal Disclaimer

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GLOSSARY OF ACRONYMS

Acronym	Extended Definition
AI	Artificial Intelligence
API	Application Programming Interface
CDW	Construction and Demolition Waste
CI/CD	Continuous Integration / Continuous Deployment
CO	Confidential
CORS	Cross-Origin Resource Sharing
DPP	Digital Product Passport
EN	European Norm
ERP	Enterprise Resource Planning
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable
GA	Grant Agreement
GDPR	General Data Protection Regulation
GUI	Graphical User Interface
HMI	Human-Machine Interface
HTTP	HyperText Transfer Protocol
ID	Identifier
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
JWT	JSON Web Token
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
MQTT	Message Queuing Telemetry Transport
MVE	Material Volume Estimation
OICD	OpenID Connect
ORM	Object Relational Mapping
OWASP	Open Worldwide Application Security Project
PU	Public
RDF	Resource Description Framework

RE	Restricted
REST	Representational State Transfer
SAML	Security Assertion Markup Language
SCADA	Supervisory Control and Data Acquisition
SCO	Supply Chain Optimisation
SDK	Software Development Kit
SLCA	Social Life Cycle Assessment
SPA	Single Page Application
SSO	Single Sign-On
UAT	User Acceptance Testing
UI	User Interface
URL	Uniform Resource Locator
UX	User Experience
WP	Work Package
ZAP	Zed Attack Proxy

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1. EXECUTIVE SUMMARY

1.1. Overview of Deliverable

Deliverable 13.5 outlines the first version of the Integrated Circular Wood Upcycling Platform developed as part of Work Package 13 in the W2W project. This platform acts as the central digital hub, bringing together key tools that support circular wood management—such as supply chain optimisation, life cycle analysis, digital product passports, and material volume estimation. The initial release focuses on defining the overall architecture, identifying integration requirements of individual tools and components, and designing user-friendly mock-ups. It lays a strong foundation for the full integration, deployment and validation of the platform in the next reporting period.

1.2. Key Objectives and Expected Outcomes

The main objectives of this deliverable are to:

- Define the architecture and the base for the platform.
- Showcase the first assembled version of the components created in WP13.
- Provide initial mock-ups and interface design elements of the platform for early-stage feedback.
- Determine the technologies that will be utilised and how they will be integrated.
- Describe the pending activities towards full validation and deployment.

Deliverable 13.5 is connected to Milestone 5 - First release of digital tools, and TRL5 technologies. This deliverable captures the first deployment of the integrated digital tools, which have been developed to the point of preliminary demonstration and internal testing. This also complements Project Outcome P2.3:

“Digital tools TRL5 validation: Work on the development of all the digital tools will commence, and a framework for the W2W platform integration will be outlined.”

The expectation is that full validation and final integration will take place in the second reporting period (M18-M36), along with the next iteration of the platform and the associated deliverables.

1.3. Contribution to WP13 and W2W Goals

Through Deliverable 13.5, WP13 target objectives are met by showcasing the first step, albeit partial, towards a fully integrated digital platform for circularity. This work also undertakes the design and partial integration and prototype realisation of these tools:

- Supports the goal of digitalizing wood upcycling flows;
- Enables cross-functional data sharing and analytics across different modules;
- Acts as a foundation for the full TRL5 validation in the next project phase;
- Reinforces W2W’s commitment to leveraging digital infrastructure for sustainable and resource-efficient value chains.

2. INTRODUCTION

2.1. Background and Context

The W2W project brings a new perspective to how we can better utilise wood waste from construction, demolition, and used furniture. At the heart of this effort, Work Package 13 is developing intelligent digital tools that support data-driven decisions — helping to promote more efficient, sustainable, and circular use of wood throughout its lifecycle. These tools are designed to track materials, estimate available volumes, optimise supply chains, and evaluate environmental impact through life cycle analysis. To bring all these elements together, Task 13.5 leads the design and development of the Integrated Circular Wood Upcycling Platform — a unified digital space that connects all tools and ensures they work smoothly and efficiently together.

2.2. Purpose and Scope of the Platform

The Integrated Circular Wood Upcycling Platform acts as the main digital hub of WP13, bringing together the core tools developed within the work package — including the Digital Product Passport (DPP), Life Cycle Analysis (LCA) tool, Supply Chain Optimisation Tool, and the Material Volume Estimation Tool. By connecting these components in a single, unified space or portal, the platform enables smooth data flow, better system-wide visibility, and smarter decision-making across the circular wood value chain.

This first version of the platform lays the foundation for what's to come. It focuses on setting up the overall structure, user interface, and integration layers, while also offering initial mock-ups to demonstrate how users will interact with the system. These early steps are crucial for building and validating the full platform in the next phases of the project.

2.3. Alignment with W2W Strategic objectives

The platform directly contributes to the W2W project's strategic objectives, including:

- Enabling digitalization and traceability across wood circularity workflows;
- Facilitating optimal cascade path selection via integrated analytical and assessment tools;
- Reducing wood waste through informed decision-making;
- Promoting interoperability, data standardisation, and alignment with emerging EU frameworks such as the Digital Product Passport;
- Acting as a demonstrator for how modular digital ecosystems can accelerate circular economy transitions.

Through this deliverable, the project marks a critical milestone in bridging technical development with applied, impact-driven outcomes.

3. STAKEHOLDER ENGAGEMENT & USE CASE SCENARIOS

3.1. PRIMARY USERS AND STAKEHOLDER ROLES

The Integrated Circular Wood Upcycling Platform has been developed to serve a diverse range of stakeholders involved in wood waste valorisation. Stakeholders are classified based on their roles, needs, and expected interactions with the platform.

Target User Groups

- Industry:
  - Industrial stakeholders (e.g. demolition contractors, recyclers, material processors) use the platform to optimise their wood cascade workflows. Tools such as the Digital Product Passport, Supply Chain Optimisation, and Material Volume Estimation enable efficient decision-making, real-time visibility, and integration across the supply chain.
- Policy Makers:
  - The platform supports regulatory bodies and policy actors by offering traceable, impact-driven insights. These can be used to inform sustainable regulation development and to monitor cascading compliance with EU circular economy goals.
- Information Sharing Entities:
  - Research organisations, technology providers, and cross-sector partners benefit from the platform's architecture as a digital environment for structured data exchange. It acts as a collaborative hub that fosters alignment, transparency, and knowledge dissemination.

Key Benefits for Stakeholders

The platform addresses the following benefits as presented in Table 1:

Table 1: Platform Benefits

Benefits	Description
Trade-Off Identification	Tools help users explore sustainability vs. cost vs. performance scenarios in cascade paths.
Improved Decision-Making	Modular dashboards and impact analytics empower stakeholders to make informed, data-supported decisions.
Environmental Impact Prediction	Life Cycle Analysis enables predictive modelling and outcome comparison.
Enhanced Sustainability	Promotes resource efficiency through reuse and valorisation of secondary wood materials.
Circular Economy Promotion	Supports digital infrastructure for closed-loop materials management across Europe.

These user roles and value propositions guide both the technical implementation and the outreach strategy of WP13, ensuring that the platform remains relevant, usable, and impactful across the full W2W ecosystem.

3.2. Use Case Examples from GA

To illustrate the advanced implementation and reasoning benefits of the Integrated Circular Wood Upcycling Platform, this segment describes use case scenarios corresponding with the W2W pilots and users' requirements established in the Grant Agreement.

Use Case 1: Demolition Contractor Optimising Wood Recovery

A contractor for demolition sets up a project for a large-area building that has a high expectation of construction and demolition waste (CDW) coming from it. The contractor using the platform has access to a tool for material volume estimation. A drone equipped with photogrammetry can provide 3D scans of the site so the contractor can use them. The data is utilised in estimating wood quantities as well as detecting reusable wood types using deep learning algorithms. The results are provided to the Digital Product Passport (DPP) so that the recyclers and processors downstream as stakeholders can have access to visibility and traceability.

Use Case 2: Recycler Matching Wood Waste to Secondary Markets

A wood recycler is in possession of a set of recovered CDW and with the help of the platform, the wood recycler attempts to match the available materials with the current demand in the market. The Supply Chain Optimization tool proposes a route which is the most sustainable and economical to the final buyer and the DPP guarantees transparency of the information given on the material which is its origin, treatment, and classification. At the same time LCA metrics are computed so as to inform the recipient's report to public LCA authorities.

Use Case 3: Product Manufacturer Creating a Recycled Product Line

A furniture producer plans to create a new product line from reclaimed wood. The platform enables the manufacturer to navigate through the catalogue of secondary wood material, impact data, and logistics scenarios for procurement. With the integrated AI capabilities of the platform, recommendation of suppliers and transport to the location that has less carbon emissions and meets quality cut off is provided. This information is subsequently uploaded to the company's ERP system.

3.3. Business Requirements Gathering

A structured and collaborative methodology [1]was adopted to collect the business requirements for the Integrated Circular Wood Upcycling Platform and its associated digital tools.

To initiate this process, a comprehensive template was developed and distributed among the technical partners. The template requested information on a per-requirement basis, structured under the following key fields:

[1] This methodology for business requirements collection—through structured partner templates, iterative feedback, and use case validation—has been effectively applied in previous collaborative EU-funded projects to ensure alignment between technical developments and end-user needs.

- Requirement Name
- Priority Level (e.g., High, Medium, Low)
- Acceptance Criteria
- Assigned Partner or Tool Owner

The main aim of this template was to provide minimal requirements that still delivered value for each tool hosted and orchestrated by the Integrated Platform, including the Digital Product Passport (DPP), Material Volume Estimation (MVE), Supply Chain Optimisation (SCO), alongside LCA analysis tools.

All partners filled in the template according to their respective tools' designs and functions. The requirements consisted of functional, usability, interface, data exchange, and integration dependency parameters. This step was not simply administrative; it was also devoted to architectural design regarding REST API interaction, orchestration through iframe visualisations, and other building block modalities. Furthermore, underpinning the minimum documentable requirements was brainstorming along with numerous other workshops.

To validate the rigor and relevance of requirements captured, several ad-hoc workshops were organized. Their composition was diverse, integrating tool developers, integration leads, as well as public authority users and recyclers who interacted within the public-domain integration use cases. Their insights were instrumental towards putting platform development on the right track in terms of field expectations versus constraints.

Special care was devoted to assure the tools supported the entire lifecycle of secondary wood materials, ranging from data acquisition and recognition, impact assessment through to value chain optimization. Other impacts included integration-related issues like authentication and touting divides between front ends and back ends, which were documented simultaneously to help set guidance for a structured implementation approach.

Thanks to this design and iterative approach, the project was able to put in place robust strategies for further development but also, during WP14, added an evolving record for features added that continued to support inline changes.

The full catalogue of requirements collected is included in **Annex I** in this report.

4. PLATFORM ARCHITECTURE AND DESIGN

4.1. OVERVIEW OF THE PLATFORM STRUCTURE AND ARCHITECTURE

Partners engaged in the W2W project will collaboratively create the following instruments:

- An implementation module and the complete design of the Dynamic Digital Product Passport (DPP).
- Secondary supply chain materialisation methodologies alongside models and algorithms for material volume estimation using data from multiple sources.
- The Procurement and Supply Chain Management Sophisticated methodology tool (SCO).
- A performance metrics counter for integrating LCA, LCCA, and S-LCA analyses.
- The Comprehensive Circular Wood Upcycling Platform.

The W2W platform is a modular and extendable digital ecosystem with a distinct single-point-of-contact user interface. The platform goal is to provide unobstructed access to DPP, MVE, SCO, and LCA through a single graphical user interface (GU) that enables performance monitoring powered by automated assessment of sustainability metrics, supply chain efficiency, and life cycle evaluation.

The system has an architecture divided within two main parts:

- Frontend section: Contains the GUI for the system and the protected user authentication system (Keycloak). It provides the entry point for using the backend functionalities.
- Backend Layer: This consists of domain-specific microservices (DPP, MVE, SCO, LCA) that handle separate functions and data processing streams. These services can communicate with the frontend using either loose or tight coupling techniques based on the intricacy of the engagement and performance requirements.

Below Figure 1 presents the first W2W platform architecture which may undergo changes in the integration phase.

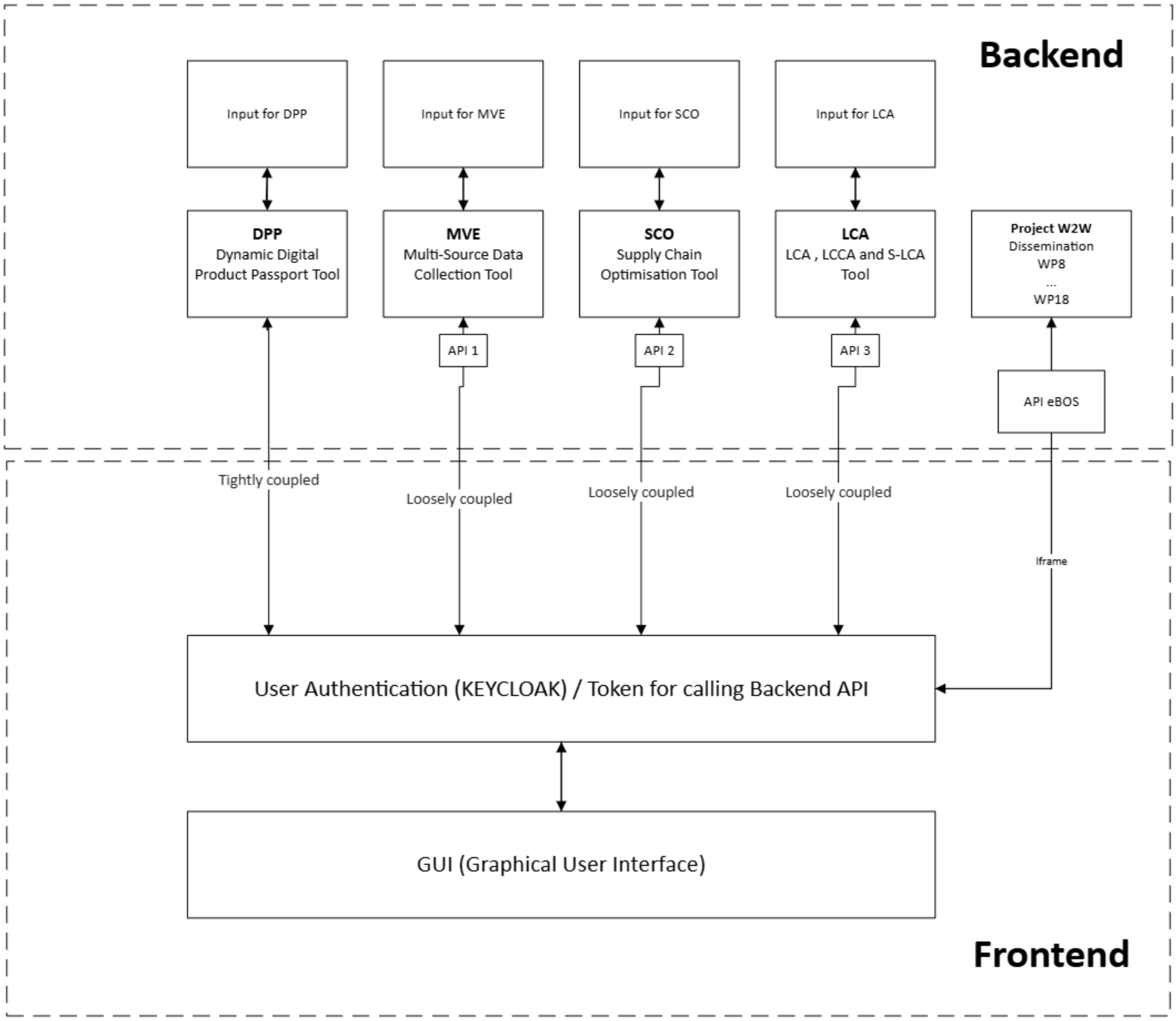

Figure 1: W2W Initial architecture

This particular Integrated Circular Wood Upcycling Platform implementation tends to follow a modular and service-oriented design. As displayed in the diagram, the backend layer's heart consists of four domain-specific tools: Dynamic DPP, Material Volume Estimation (MVE), Supply Chain Optimisation (SCO), and LCA, LCCA, S-LCA. All of them accept structured input data, work independently, and expose their capabilities through specific APIs (API 1, API 2, API 3, etc.). The coupling approach varies across microservices: DPP is tightly coupled for synchronous invocation while MVE, SCO, and LCA are loosely coupled for a less restricted integration flexibility and scale during later incorporation phases. An API link to eBOS alongside an integrated iFrame to other project work package components enables dissemination functionalities through external project work package modules.

User access on the frontend layer is provided by a unified GUI which serves as a single point of entry for all integrated services. A User Authentication module (Keycloak) manages access control through secured token issuing system for backend API calls. This design provides role-based access, secure communication, and consistent user experience across tools. Additionally, custom and subsequent services, as well as third-party modules, can be added without alterating the existing structure, promoting platform durability and flexibility, while ensuring a separated concern architecture of frontend versus backend systems.

4.2. Modular Design

The design of Integrated Circular Wood Upcycling Platform is based on modular architecture which allows for greater flexibility, scaling and integration of new digital tools developed in WP13. This enables the platform to be further developed over time for enduring sustainability to meet changing stakeholder needs and withstand new technical innovations.

Each module, DPP or LCA Tool or Volume Estimation or Supply Chain Optimisation, is implemented as a stand-alone functional unit with a complete set of APIs and modules that can communicate with each other through well-defined protocols. This guarantees that every tool, while contributing to the thematic orchestration of the platform, can function on its own. The modular arrangement also enables updates, testing, and isolation deployments that lower maintenance burdens, improving development workflow resilience.

GUI Design Principles

The graphical interface of the platform was designed to comply with universally recognized and accepted GUI (Graphical User Interface) Design Principles, ensuring coherent representation and good usability throughout all modules. These principles will guide the design of interfaces for all other modules notably the initial mock-up designs and all other versions of the interfaces that will come after it.

The main principles [2] (Table 2) considered include:

Table 2: HMI Design Principles

Design Principle	Guidelines
Understand the User	Consider stakeholder roles, goals, and tasks. Leverage prior user experience for intuitive interaction.
Ease of Use	Simplify workflows and use familiar metaphors to ensure quick engagement.
Visual Hierarchy & Clarity	Organise and prioritise information visually; help users grasp structure and importance.
Minimalism & Simplicity	Display only essential information. Reduce clutter and emphasize common actions.
Aesthetically Pleasing	Use contrast, grouping, alignment, and subtle graphics for a clean, appealing interface.
Consistency	Ensure uniform layout, behaviour, and appearance across screens/modules.
Effective Visual Representation	Use charts, graphs, and maps to make complex data readable and insightful.
Interactivity	Enable dynamic exploration of data through filtering, switching views, or interactive widgets.

[2] The GUI design principles presented here are widely adopted across eBOS's European R&I projects and have been consistently implemented in several platforms to ensure usability, accessibility, and user-centric interaction.

Responsive Design	Interface adapts across desktops, tablets, and smartphones; maintains functionality and clarity.
Performance Optimisation	Ensure fast loading and responsiveness, even with large datasets or visualisations.
User Control	Allow users to control their flow and avoid disruptive interruptions.
Efficiency	Minimise unnecessary eye/hand movement. Streamline task execution paths.
Recovery	Provide undo/redo options and data recovery to prevent loss from system issues.
Feedback & Interaction	Offer real-time feedback and highlight errors or confirmations clearly.
Contextual Information	Provide tooltips, explanations, or in-place guidance to clarify data or functions.
Data Protection	Ensure all sensitive data is securely handled and access-controlled.
User Permissions	Role-based access allows users to interact with only the features and data relevant to them.
Modular Design	Support scalability and future extensions by allowing independent module upgrades and integrations.

These principles aid in achieving the general design philosophy of the platform as accessible, efficient, and usable by a wide variety of stakeholders, including public authorities and demolition contractors.

Cross-Browser and Multi-Device Compatibility

The platform is being developed with full cross-browser and multi-device compatibility to support different operational contexts. This allows users to interact with the platform using desktop computers, tablets, or mobile phones with any major web browser.

The following technologies are used:

- HTML5: Enables the addition of documents' multimedia features along with responsive layout capabilities while providing semantic structure.
- CSS3: Enables flexible styling, media query application, and management of layout changes on all devices for responsive designs.
- JavaScript: Provides non-static content, dynamic features, and interactive components for the whole platform.

These technologies, along with modern testing tools and web development best practices, ensure that the platform offers a coherent, high-quality user experience, regardless of device or environment of access.

4.3. Initial Mock-ups and UX Considerations

This section showcases the mock-ups of the graphical user interfaces (GUIs) of the Integrated Circular Wood Upcycling Platform and captures in detail its multi-level visual, navigational site maps, and system interactivity. These mock-ups illustrate the Digital Product Passport, Volume Estimation, Supply Chain Optimisation, Lifecycle Assessment tools, and other within-system key features. This mock-up features aid stakeholders in capturing initial testing validation exercises templates, confirming accuracy adherence to design principles and responsiveness to different scenarios and stakeholder needs.

Starting from the intended purpose of each user role and the goals to be achieved, the W2W GUI aims to offer a basic visual layout with a systematic and structured approach for recyclers, material processors, public authorities, and platform administrative users of varying degrees. The interface allows for effortless navigation and interactivity, employing a common vernacular to help users perform data-informed tasks and facilitate cooperation across different sectors and regions. It affords users the capability to monitor, evaluate, and manage material flows alongside environmental impacts in relation to circular wood upcycling initiatives, thus integrating essential platform capabilities.

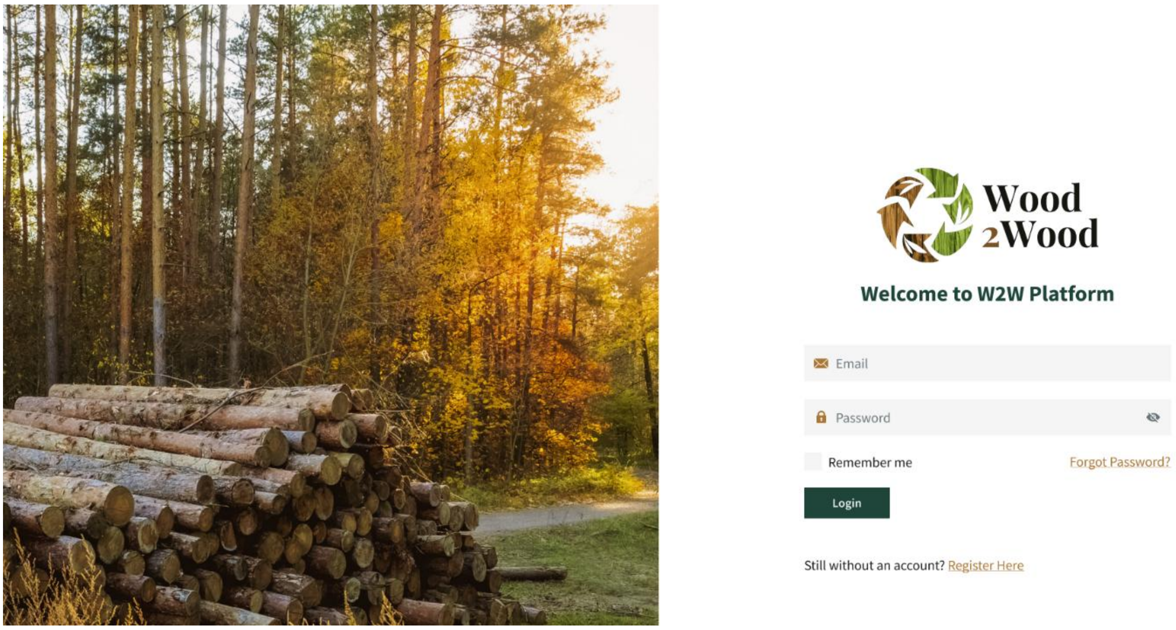

Figure 2: Login screen

This is the platform's entry point (Figure 2). The left side contains themed imagery of timber and forest portraying timberland sustainability. The right half displays a clean login page with an email and password section, a 'Remember me' checkbox, and links for password recovery and registration. It illustrates simplicity, accessibility, and visual clarity.

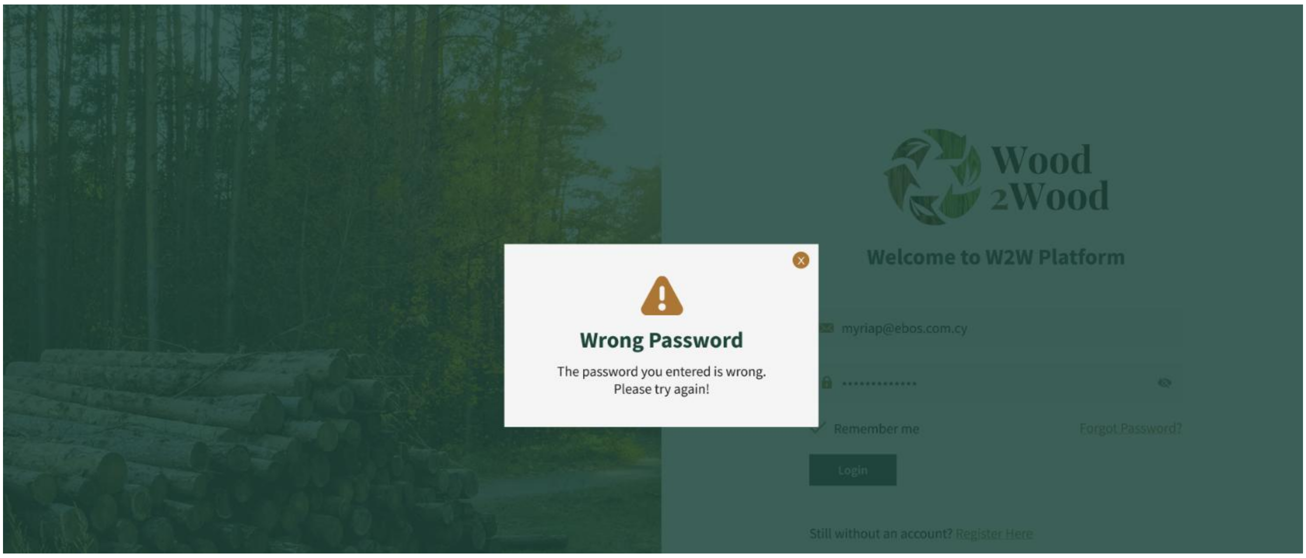

Figure 3: Wrong password notification

A warning icon along with a message providing immediate feedback ensures that users understand the issue and can retry (Figure 3). This type of feedback reinforces responsive design and real-time interaction.

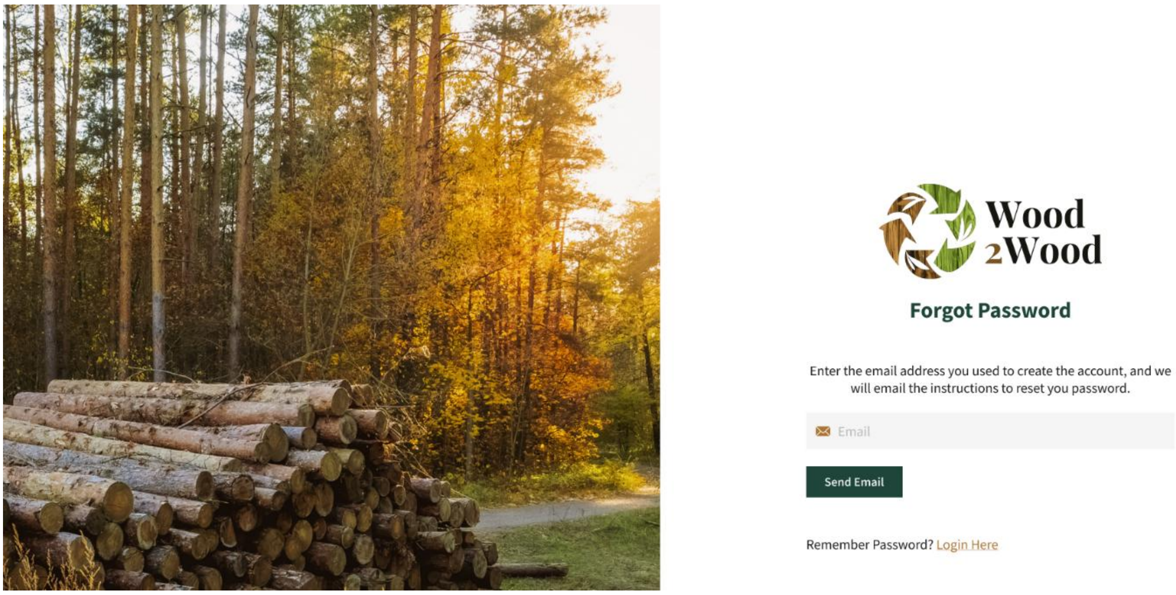

Figure 4: Forgot password

Users unable to recall their password are directed here (Figure 3). This interface includes a single email field and contains a brief message explaining the password reset process. This guarantees focal simplicity within the password reset process.

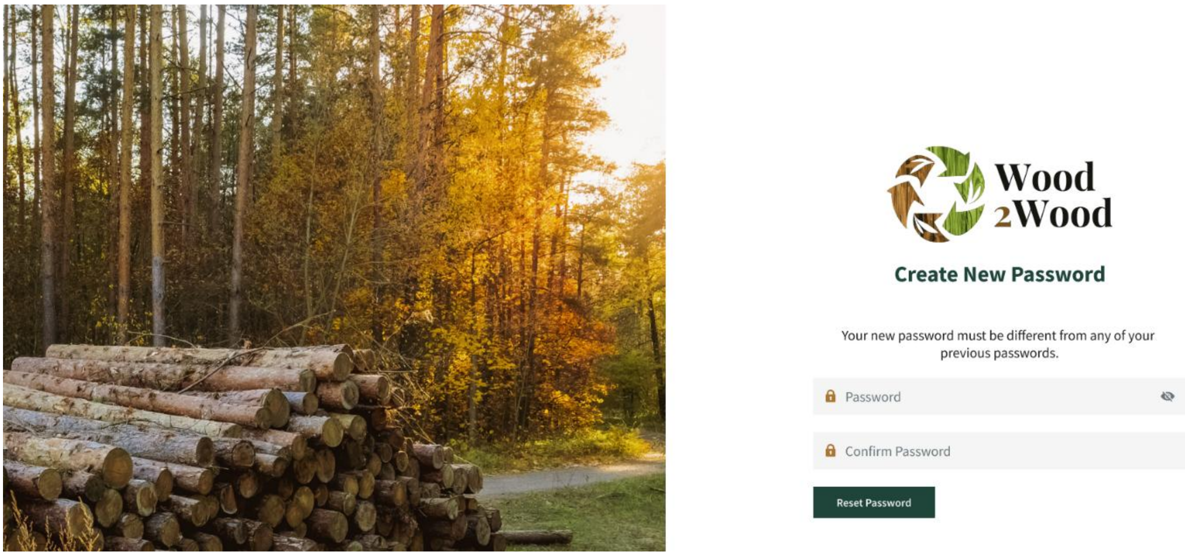

Figure 5: Create new password

This screen enables the user to set a new password (Figure 5). The layout is consistent with other login-related forms and features toggles for showing/hiding password, along with guidelines to bolster and ensure uniqueness for the set password.

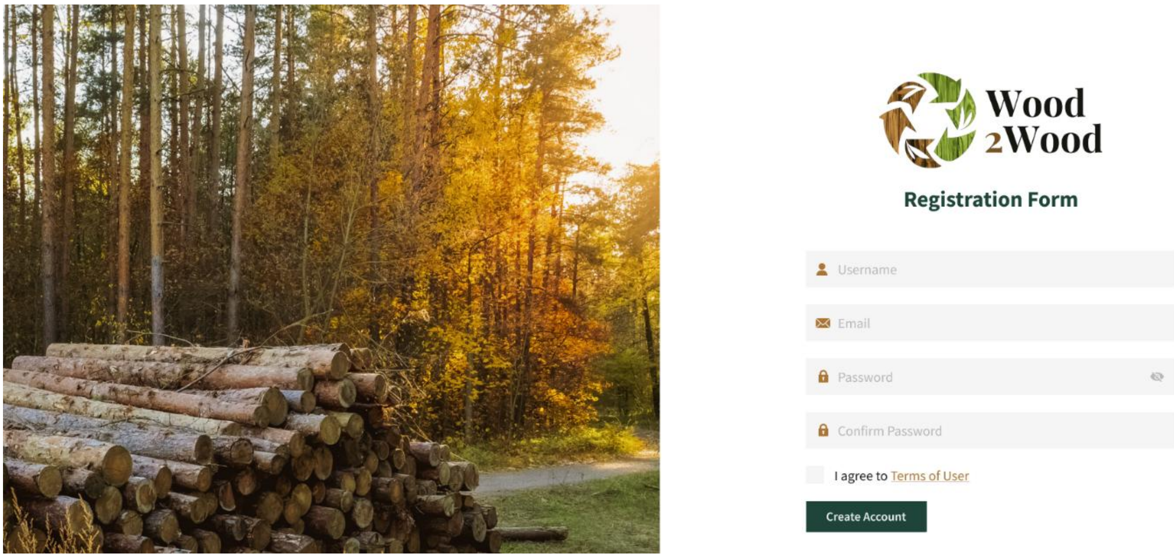

Figure 6: Registration form

The user registration screen features username, email, password, and agreement to the terms of use (Figure 5). All fields follow the spacing norms for clarity which are also designed with accessible formats. This screen adheres to form usability best practices.

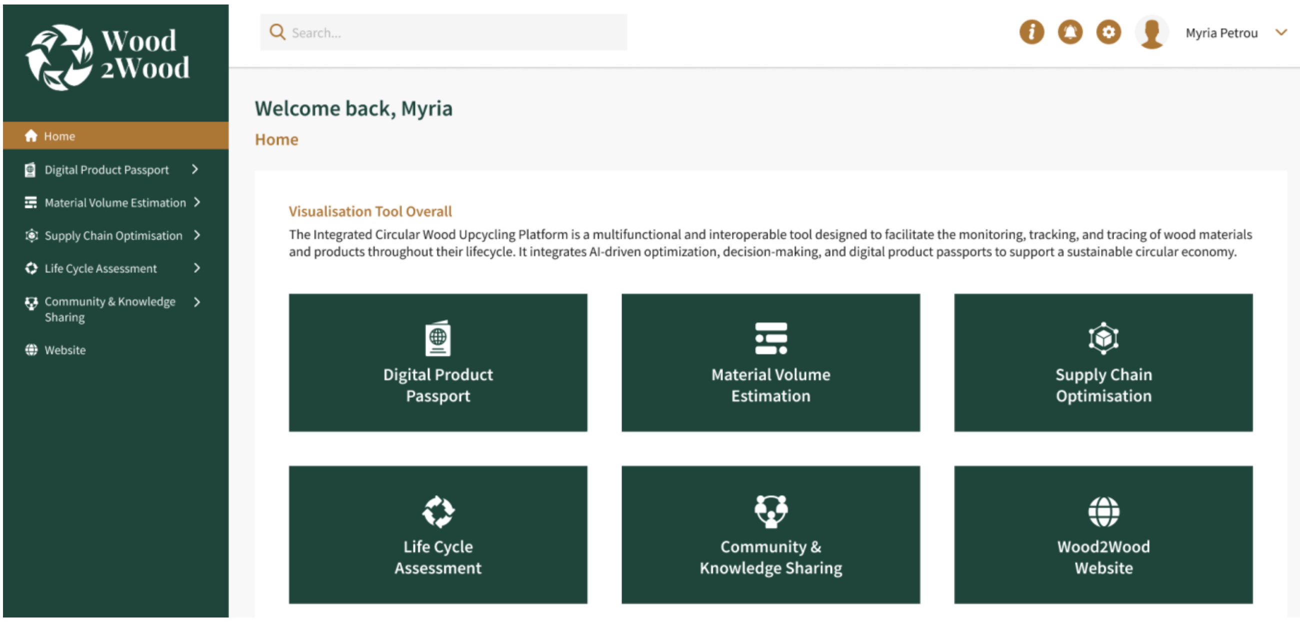

Figure 7: Dashboard Home

Upon logging in, users are directed to the dashboard (displayed in Figure 7). The six predominant tools of the platform are displayed as tiles for ease of access and interaction. This particular arrangement facilitates order of importance, ease of navigation, and task categorisation: Digital Product Passport, Material Volume Estimation, Supply Chain Optimisation, Life Cycle Assessment, Community & Knowledge Sharing, and the W2W Website.

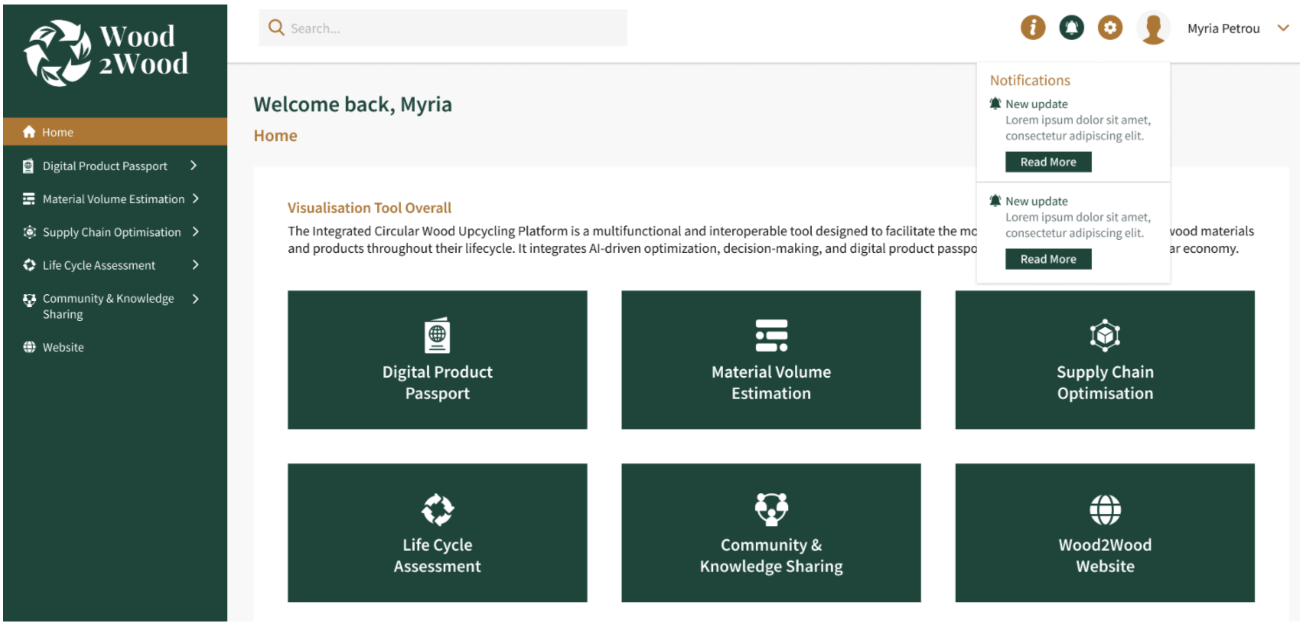

Figure 8: Notification's dropdown

The updates available can be accessed through the bell icon located at the top right of the page, as demonstrated in Figure 8. All updates available are listed in a dropdown menu with associated text preview and a button labelled "Read More." The way this information is presented is unobtrusive and provides instant information flow.

5. FUNCTIONALITIES AND FEATURES

The Integrated Circular Wood Upcycling Platform acts as a single digital ecosystem intended to host and integrate all tools developed in WP13. While initially lacking in holistic user experience, secure access, and interoperability, the platform now offers streamlined access, visualisation, and coordination functionalities. These are delivered through the integration of the following core tools:

- **Digital Product Passport (DPP)** for end-to-end tracing
- **Material Volume Estimation Tool (MVE)**
- **Supply Chain Optimisation Tool (SCO)**
- **Life Cycle Analysis Computation Tool (LCA)**
- **Platform Orchestration and Interface Layer** for tool access and visualisation

Each tool is briefly described in the following sub-sections. Together, they empower sustainable decision-making across wood value chains by combining data-driven insights, automation, and user-friendly access.

5.1. End-to-end Tracing Module and Digital Product Passport

The Digital Product Passport (DPP) offers an all-encompassing traceability and documentation solution for wood products and their by-products within the entire cycle, as elaborated in Deliverable D13.1 [1]. DPP guarantees sustainability and compliance through traceability and data transparency within different regulatory environments. It captures critical tracking events, verification data, and sustainability credentials. The module provides data interoperability with external systems while being directly routed through the platform, enabling real-time updates and insights.

5.2. Material Volume Estimation Tool

The MVE Tool highlighted in Deliverable D13.2 [2] aims to accurately estimate the volume of Construction and Demolition Wood (CDW) waste using multimodal data such as 3D point clouds (LiDAR or photogrammetry) and 2D images, and it employs object detection and recognition through AI. Fast, automated, site-specific assessments of materials obtainable at a site can be achieved, thanks to its advanced capabilities. The tool captures volume estimates to inform the DPP and other decision components on the platform.

5.3. Supply Chain Optimisation Tool

According to the findings of Deliverable D13.3 [3], the Supply Chain Optimisation (SCO) Tool extends its functionality to simulation and optimisation of logistics, inventory, and transportation for secondary wood material’s supply and demand. It also offers scenario modelling, eco-impact estimation, dynamic demand forecasting, and risk analysis. By enabling the development of streamlined, adaptable, and sustainable supply chains, the tool aids stakeholders in achieving economic and environmental objectives.

5.4. Life Cycle Analysis Computation Tool

The LCA Computation Tool described in Deliverable D13.4 [4] enables users to perform environmental, social, and economic sustainability evaluations (LCA, SLCA, LCCA) of products and materials. It accepts data from several W2W components, breaches ISO standards, and has ML-based solutions for enhancing the quality and completeness of data inventories. The results contain impact evaluations and forecasts, providing a foundational structure that aids planners in sustainable decision-making.

5.5. Integrated Circular Wood Upcycling Platform

As described in Deliverable D13.5, the platform is a modular and interoperable digital ecosystem that integrates all the aforementioned tools. Its design includes a single frontend, managed user authentication, and interactive graphics dashboards. While the platform does not implement the business logic of the tools, it enables through access, orchestration, and visualisation of the services. This serves to empower stakeholders with insights and control over the circular wood processes.

6. DEVELOPMENT PROCESS AND INTEGRATION

6.1. INTEGRATION PROCESS AND METHODOLOGY

eBOS is responsible for the integration of all developed tools under WP13 and enhanced in WP14 into one multifunctional and cohesive platform - Integrated Circular Wood Upcycling Platform. With this platform, end-users will be able to monitor, track, and trace materials, and products across the whole value chain using a Digital Product Passport (DPP) that is updated in real time.

The platform will offer a wide array of functionalities, including:

- Enhanced visualisation and control interfaces,
- AI-driven optimisation and decision-making tools,
- Capabilities for modelling, simulation, and scenario-based assessment.

The design aims at enabling a diverse set of stakeholders, ranging from operators and formulators, recyclers, public authorities, and even standardisation bodies, to perform their work seamlessly through the required supply chain interactions, communication, and coordination.

Furthermore, the platform will:

- Enable the exploitation of Key Exploitable Results (KERs) by fostering communities of practice for resource exchange and stakeholder matchmaking.
- Serve as a repository for documentation of results, statistical analyses, identified barriers, and best practices.
- Support skills development activities under WP16–WP18.
- Contribute to dissemination and knowledge-sharing efforts covered in WP19–WP21.

Pilot partners will be important in the data collection and integration processes because of their SCADA system knowledge and multiprotocol data interfacing skills, as well as their experience in developing software modules for remote communication and data compilation. These components are intended to operate in Linux-based distributed systems, and will be mounted in Docker containers or other encapsulation methods for easy portability and lower interfacing effort.

Integration Methodology

The Integrated Circular Wood Upcycling Platform has been designed with integration flexibility in mind. It supports both tightly coupled and loosely coupled integration approaches, depending on the technical architecture and preferences of the contributing partners. This adaptability ensures that diverse tools — regardless of their internal design — can be connected to the platform efficiently, promoting interoperability and ease of maintenance across the ecosystem

Frontend–Backend Integration Methodology

Coupling refers to how closely connected the frontend (what the user sees and interacts with) is to the backend (the server, databases, APIs, and logic).

- Tightly Coupled = Strongly dependent on each other.
- Loosely Coupled = Minimally dependent, more independent.

Tightly Coupled Integration

Characteristics:

- The frontend and backend are designed together, often in the same codebase or framework.
- Direct function calls or shared libraries/models between the frontend and the backend.
- Typically, a monolithic architecture.

Benefits:

- Faster development: Everything is in one place.
- Easier debugging: Trace errors across frontend/backend quickly.
- Shared data models: Less need to transform data.
- Good for small apps or MVPs where speed > scalability.

Drawbacks:

- Hard to scale: You can't update the frontend without risking backend issues (and vice versa).
- Limited flexibility: Harder to switch tech stacks (e.g., replace backend without redoing frontend).
- Tight versioning: Both sides must be in sync.

Common Communication:

- Direct calls inside the same server (no network needed).
- Synchronous protocols like:
- Function calls (if in the same codebase).
- REST (if separate but still tightly integrated).

Loosely Coupled Integration

Characteristics:

- Frontend and backend are separate applications.
- Communicate via APIs (e.g., REST, GraphQL).
- Can be deployed independently.

Benefits:

- Scalability: You can swap out or scale either side independently.
- Flexibility: Easier to change technology stacks (e.g., React frontend + Node.js backend, swap backend later).
- Improved maintainability: Clean API boundaries.
- Good for microservices architecture.

Drawbacks:

- More complex setup: Need API contracts, versioning, and CORS handling.
- Potential performance hit: Network latency between frontend and backend.
- More DevOps: Separate deployments, CI/CD pipelines.

Common Communication:

- HTTP-based APIs:
    - REST

    - GraphQL
    - gRPC (sometimes)
- WebSockets for real-time features.
- Message queues (e.g., Kafka, RabbitMQ) in advanced setups.

Table 3: Example Scenarios

Scenario	Tightly Coupled	Loosely Coupled
Small internal tool	Monolithic app (Django/Flask with Jinja templates)	React frontend + Flask backend via REST API
Large SaaS product	Not recommended	React/Angular + Node/Go backend via GraphQL
Real-time dashboard	Monolith with WebSockets	SPA + backend with WebSockets or MQTT

Table 3 provides some example scenarios between the two different integrations.

Basic Instructions to Implement:

Tightly Coupled:

1. Choose a full-stack framework (e.g., Django, Laravel).
2. Build frontend templates within the backend.
3. Use shared models/ORM for data.
4. Keep deployment as one app.

Loosely Coupled:

1. Build the frontend (e.g., React, Vue).
2. Build backend as an API (e.g., Node.js/Express, Django REST Framework).
3. Define API contracts (OpenAPI/Swagger helps!).
4. Handle CORS (cross-origin requests).
5. Deploy separately (e.g., Netlify for frontend + Heroku for backend).

Table 4: Tightly and Loosely Coupled Integration Summary

	Tightly Coupled	Loosely Coupled
Dependency	High	Low
Best for	Small apps, MVPs	Scalable, modern apps
Flexibility	Low	High
Performance	High (local)	Slight network overhead
Setup complexity	Simpler	More complex (needs APIs, CORS)
Common Protocols	Direct calls, REST	REST, GraphQL, WebSockets
Deployment	Single app	Separate frontend & backend deployments

Table 4 summarises the main differences between the two kinds of integration (Tightly vs Loosely).

The integration methodology reflects a hybrid coupling approach:

- **Tightly Coupled Integration:**

The DPP tool is currently integrated at the frontend and therefore, high-speed data transfers are possible. The GUI is capable of issuing queries and performing updates, which means that data retrieval and interaction with the system are done with very little abstraction and are smoothly integrated.

- **Loosely Coupled Integration:**

REST APIs MVE, SCO and LCA possess active functionalities which are exposed and serve as API 1, API 2, and API 3 respectively. Through the authorised tokens proposed by Keycloak, the frontend is transformed into a client and performs asynchronous communications via the exposed APIs.

- **External Integration:**

The platform also supports external data ingestion (e.g., from WP18), via open API endpoints (API eDDS), enabling data flow from third-party sources without hard dependencies.

Each integration path is mediated by authentication tokens, ensuring that only authorised users and services can initiate API calls.

Keycloak integration

In the scope of the W2W project, for the user authentication process, Keycloak will be used.

At this stage, it has not been decided who will host Keycloak; therefore, the architecture could be adjusted, as well as the integration of Keycloak.

Keycloak Feasibility/Suggested Solution

Objective: Provide seamless single sign-on (SSO) across 4 independent web tools integrated into a central portal via iframes.

Proposed Solution:

- Use Keycloak (hosted by eBOS) as a centralised Identity Provider (IdP).
- Each partner integrates their web app (tool) with Keycloak for authentication via OpenID Connect (OIDC) or SAML.
- Users will log in once via the W2W portal and gain access to all iframe-embedded tools without separate logins.

Key Technical Considerations:

- Each partner's app must support OIDC or SAML authentication.
- Each app must be configured as a Keycloak client with proper redirect URIs.
- CORS, iframe embedding, and cookie-sharing policies must be configured appropriately (e.g., SameSite=None + HTTPS).
- User roles and permissions can be centrally managed or delegated via token claims.

Technical Summary

Centralised Authentication via Keycloak – Integration Overview

Goal: Enable centralised authentication for all partner tools embedded in the common W2W portal via iframes.

Architecture Summary

- Portal: Hosts the iframe containers

- Keycloak: Central Identity Provider (hosted by eBOS)
- Partner Tools: Independently hosted web apps configured as Keycloak clients

Table 5: Key Technical details

Component	Description
Auth Protocol	OpenID Connect (OIDC) preferred; SAML as fallback
Token Type	Access Token (Bearer JWT), ID Token
User Login	Happens once via the portal or the Keycloak login page
User Roles	Optional: Can be issued via Keycloak token claims
SSO Behavior	Once authenticated, the token is reused across iframes
Security Settings	HTTPS required; SameSite=None cookies for iframe sharing
Client Config	Each tool will be registered as a “client” in the Keycloak realm

Table 5 outlines the key technical details applied across the platform’s integrated tools.

Partner Integration Checklist

Each partner must:

1. Confirm support for OIDC or SAML
2. Share their tools:
   a. Base URL
   b. Redirect URIs
3. Configure their application to accept tokens from Keycloak
4. (Optional) Parse roles/claims from tokens to enable role-based access

We will provide:

1. Keycloak server URL and realm info
2. Client credentials (Client ID, Secret)
3. Redirect URI rules
4. Sample configs or SDK references

User Login Flow Diagram

Here (Figure 9) is a visual of the architecture and login flow:

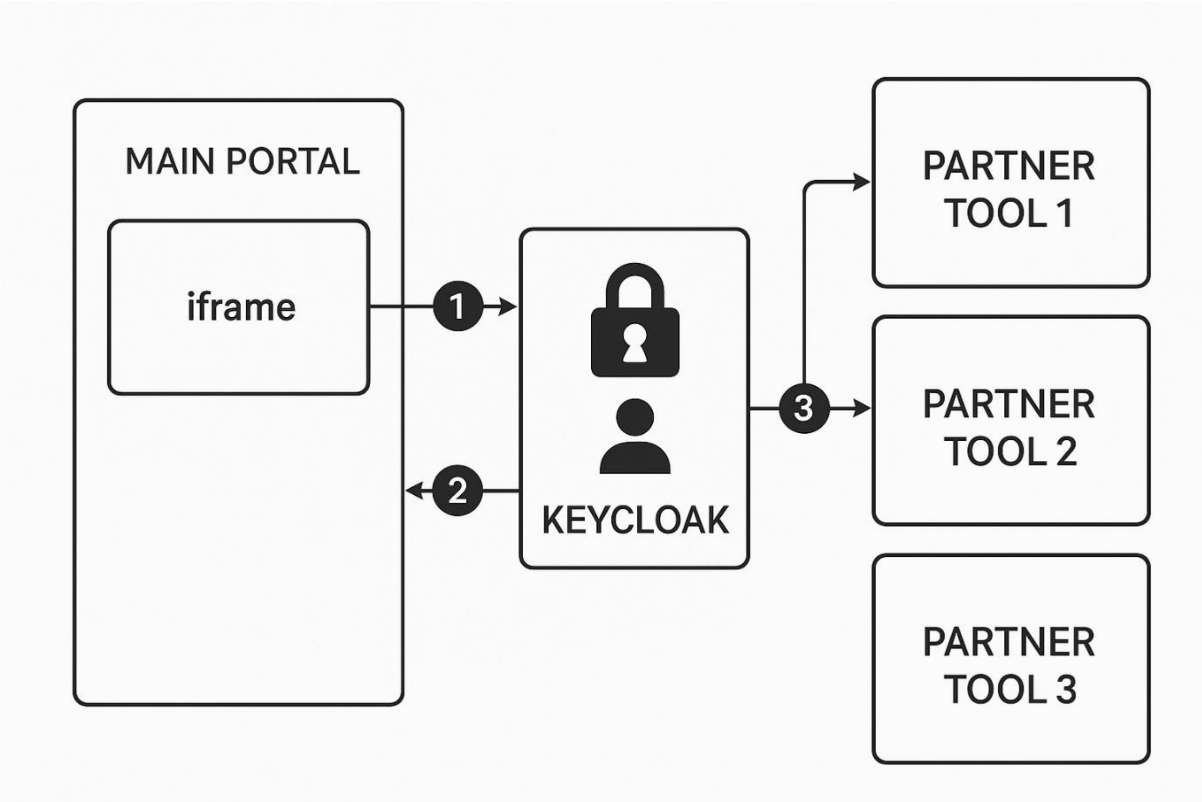

Figure 9: User Login flow

Flow Steps:

1. User accesses the main W2W portal and logs in
   a. Keycloak issues token
   b. Token is used to access all tools without re-authentication
2. User clicks to open a tool in an iframe
3. Tool UI is displayed in iframe without needing to log in separately.

Sample Keycloak Client Configuration

For each partner, eBOS will create a Keycloak client with the following sample settings:

```
{
  "clientId": "partner-tool-1",
  "rootUrl": "https://tool1.partner-domain.com",
  "redirectUris": ["https://tool1.partner-domain.com/*"],
  "protocol": "openid-connect",
  "publicClient": false,
  "secret": "generated-client-secret",
  "standardFlowEnabled": true,
  "implicitFlowEnabled": false,
  "directAccessGrantsEnabled": true
}
```

6.2. Development Methodology

The W2W platform is developed using a DevSecOps approach, incorporating:

- Agile and iterative development cycles (2-week sprints).
- Continuous Integration and Continuous Deployment (CI/CD) pipelines.
- Regular integration checkpoints across WPs to ensure end-to-end compatibility.

Key elements include:

- Early stakeholder feedback to validate feature relevance.
- Incremental integration of backend services.
- Frequent security audits and compliance testing (e.g., GDPR, ISO27001).

Parallel workstreams:

- Backend teams deploy micro-frontends to be consumed in iframes.
- Frontend developers manage iframe layout, state, and token management.
- Continuous integration pipelines test iframe-rendered modules separately and as embedded units.

According to best practice this methodology reduces interdependencies, allowing each team to iterate independently.

6.3. Technologies and Tools Used

For maintaining modularity, flexibility, and ensuring smooth interaction between components, the Integrated Circular Wood Upcycling Platform was developed using a contemporary technology stack for the frontend, backend, authentication, and orchestration layers. The choice of tools and frameworks prioritised the specific criteria of interoperability, efficiency, and compliance with emerging standards of open-source software. The diverse technologies and tools facilitated the platform's layered architecture, as described in Table 6 which highlights the platform's key data technologies and tools.

Table 6: Technologies and Tools used

Layer	Technologies
Frontend	ReactJS / Angular, HTML5, Bootstrap
Authentication	Keycloak [6] (OpenID Connect, OAuth2), JWT
Backend	Python (Flask, FastAPI [7]), Java (Spring Boot), Node.js
APIs	REST, JSON, Swagger/OpenAPI for documentation
Orchestration	Docker for containerisation, Kubernetes for deployment (planned)
Version Control	Git (GitHub/GitLab), GitHub Actions / Jenkins for CI/CD

IFrames allow integration of both static visualisations and interactive backend-generated dashboards, improving modularity.

6.4. Components Integration

The platform integrates the following components:

- DPP (Dynamic Digital Product Passport)
    - Integration: Tightly coupled
    - Function: Collects and displays detailed product-level sustainability data.
    - Data Flow: GUI directly interacts with the backend without an intermediate API layer.
- MVE (Multi-Source Data Collection Tool)
    - Integration: Loosely coupled via API 1
    - Function: Collects multi-source environmental data.
    - Architecture: Stateless API endpoints ensure scalability.
- SCO (Supply Chain Optimisation Tool)
    - Integration: Loosely coupled via API 2
    - Function: Simulates and optimises supply chain flows under various constraints.
- LCA (Lifecycle Assessment Tool)
    - Integration: Loosely coupled via API 3
    - Function: Performs LCA, LECA, and SLCA computations based on harmonised input data.
- W2B Data Sources / External Integrations
    - Integration: External API interface (API eDDS)
    - Function: Imports datasets from relevant WPs and other external repositories.

Each backend component (DPP, MVE, SCO, LCA) is integrated using a REST API and visual output rendered in an iframe as presented in Table 7.

Table 7: Components Integration

Module	Integration Type	API	Iframe Rendering
DPP	Tightly Coupled	API1	Direct GUI embed
MVE	Loosely Coupled	API2	iframe
SCO	Loosely Coupled	API3	iframe
LCA	Loosely Coupled	API4	iframe

6.5. Standards, APIs, and Semantic Interoperability

The architecture enforces interoperability and standardisation through:

- API Standards:
    - RESTful APIs documented using OpenAPI 3.0 (Swagger).
    - JSON as the primary data interchange format.

- Authentication Standards:
  - OAuth 2.0 and OpenID Connect implemented via Keycloak.
  - Token-based access control (JWT) used across all API layers.
- Semantic Interoperability:
  - Use of shared vocabularies and ontologies for sustainability data (e.g., EN ISO 14040 series for LCA).
  - RDF/Linked Data support for selected endpoints.
- Data Licensing and FAIR Compliance:
  - All shared datasets are governed under FAIR principles (Findable, Accessible, Interoperable, Reusable).

Semantic alignment ensures iframe-embedded tools interpret and display data consistently.

7. TESTING

7.1. Testing Methodology

To guarantee the strength, dependability, and user-friendliness of the Integrated Circular Wood Upcycling Platform, has defined and executed a thorough testing methodology. This approach includes multiple strata of testing like unit testing, integration testing, system testing, security testing, and user acceptance testing. Each layer focuses on different parts of the platform, starting from backend services and ending with complete workflows, security measures, as well as longitudinal and cross-sectional integration. Some attention has been paid to embedded tools through iframes, which necessitated specialised validation steps for rendering, cross-origin communication, and interaction accuracy. Below Table 8 summarises the strategies, provenance and shed tools, and processes utilised in the context of the testing.

Table 8: Testing methodology

Testing Layer	Tools / Process
Unit Testing	PyTest, JUnit, Mocha—testing backend services in isolation
Integration Testing	Postman, REST-assured, custom scripts—verifying API connectivity with GUI
System Testing	Manual and automated end-to-end tests simulating full user workflows
Security Testing	OWASP ZAP [5], static code analysis tools—focus on authentication and API vulnerabilities
User Acceptance Tests	Performed iteratively with domain experts in WP1/WP7 to validate GUI and tool flows

Iframes and iframed contexts give both integration and unit testing an additional emphasis of focus.

- Embedded Rendering Tests: Ensure iframe content loads and communicates correctly.
- Cross-Origin Security Tests: Validate token-based access control.
- UAT with Iframe Contexts: Confirm that users can interact with iframe-embedded tools within the platform layout.

Test automation across iframe boundaries is orchestrated through the combination of Cypress, Postman, and Selenium.

8. CHALLENGES, RISK ASSESSMENT, AND MITIGATION STRATEGIES

8.1. KEY CHALLENGES ENCOUNTERED

The Integrated Circular Wood Upcycling Platform incurred coordination and technical issues within Task 13.5. The consolidation of various digital instruments created over WP13 into a single cohesive unit was challenging because integration, flexibility, and scaling had to be managed simultaneously across diverse components.

There were tool-specific discrepancies regarding the dimensions of data and the methods of system interaction. This complexity needed multiple cycles of alignment to specification definitions and refinement iterations. Also, the designer's input and documentation were not always delivered on schedule, which stalled integration and testing processes.

There were issues related to the compatibility of containerisation from deployment such as different development and execution environments. These issues led to the need for tests in baselines that were not controlled and for shared governance in guided conditions.

Accommodating the platform's design to rising frameworks like the Digital Product Passport and LCA data modelling of processes increased the problem's difficulty. Fulfilling "need to comply" clauses demanding past compliance while progress was ongoing posed a challenge because supporting retroactively adapting to evolving regulations was constantly oscillating in the progress strategy.

Lastly, early implementation of protective measures against the uncontrolled exposure of sensitive data underpinning pilots was necessary to ensure dataset security, data protection governance compliance, robust access management, and security governance.

8.2. RISK ASSESSMENT AND MITIGATION STRATEGIES

As part of Task 13.5 the most acute risks have already been encountered and their mitigation strategies adopted during the phase of the task has been annexed into the below table (Table 9) for ease of reference.

Table 9: Risk Assessment and Mitigation Strategies

Risk ID	Risk Description	Impact	Mitigation Strategy
R1	Misalignment between tools' data formats and integration requirements	High	A common data model was introduced early. Continuous coordination and refinement of interface specifications were maintained to ensure tool interoperability.

R2	Delayed input or documentation from tool developers	Medium	A buffer was included in the integration timeline. Direct bilateral partner communications ensured clarification and prioritisation of critical information.
R3	Docker/module deployment incompatibilities across environments	Medium	Containerisation guidelines were enforced. Early compatibility testing helped standardise execution environments and reduce fragmentation.
R4	Security and access control gaps during early development	High	Role-based access, authentication, and encrypted communications were implemented early. Security audits and GDPR checks were incorporated into platform testing.

These risks and challenges were managed through agile problem solving, systematic technical design, and regular inter-partner communication across the different partners. This control action enabled the coordinated development of the platform alongside the W2W project requirements and stakeholder expectations.

9. ROADMAP AND SUSTAINABILITY PLAN

9.1. Planned Enhancements for Version 2 (Final Version)

The Integrated Circular Wood Upcycling Platform (Version 2), which is expected in the second reporting period, will aim at incorporating all the tools developed throughout WP13 and WP14 digitally. The tools will be integrated and synchronised within the platform's architecture, ensuring no interoperability conflicts or functional redundancy with other components.

Key enhancements will include:

- The completed versions of digital tools, such as the Digital Product Passport, Material Volume Estimation Module, LCA, and Supply Chain Optimisation, will be incorporated into the platform.
- Validation of the platform through the use of pilot data and use case scenarios provided by the project partners to validate operational functionality.
- External user testing (recyclers, public authorities, and industry actors) to test their interaction with the platform in relation to usability, functionality, and effectiveness and conduct real-life application evaluation.
- Testing and evaluation processes relative to system, functional, and security objectives to evaluate performance, interoperability, and compliance with defined standards, policies, and procedures.
- Applying user feedback received during internal assessments and user walkthroughs to ensure the UI/UX is optimised for ease of use even by non-specialists.

These enhancements aim to deliver a robust, validated, and industry-ready version of the platform by the conclusion of the project.

9.2. Long-Term vision, Openness, and Sustainability

The most distant vision of the Upcycling Integrated Circular Wood Platform is in concert with the aims of the W2W project, which is to automate the processes of secondary wood material, wood digitals, and the entire secondary wood industry value chain, monitoring Circul Economy through transparent ecosystems.

Pursuant to the terms of the Grant Agreement (GA), the platform aims to achieve:

- Replicability and Openness: Its architectural framework promotes the possibility of being reused and applied across other circular value chains and materials apart from wood, which supports expansionism.
- Continued use outside the project: The platform's modular and interoperable design allows for augmenting and integrating with additional systems, services, and datasets external to the platform.
- Social interaction: The platform will act as a social network for all stakeholders within the upcycling value chain by creating communities of practice for co-participation in resource and knowledge exchange.
- The platform will still be relevant towards policy updates due to their alignment with standardisation and policy developments like the Digital Product Passport and circular economy indicators.

- Integration with other industrial systems (e.g., SCADA, ERP, etc.) and containerised applications like Docker enables effortless deployment into operational settings.
- The long-term sustainability of the project will be ensured via its possible commercial use, continued open-source development for some components, and incorporation into later R&I projects or clusters.

The described approach will ensure that further development of the platform will transform it into a fully functional digital asset capable of providing ongoing benefits after the project concludes. Through possible commercial investment avenues, open-sourcing some components, and alignment with strategic R&I policies and standardisation activities, the platform avoids obsolescence and meets the needs of the circular economy ecosystem.

10. CONCLUSION

10.1. SUMMARY OF ACHIEVEMENTS

To the best of our ability, the design, development, and integration of the Integrated Circular Wood Upcycling Platform have been captured in this deliverable as a part of Task 13.5 of the W2W project. Assisting the platform, a plethora of digital tools have been developed such as the Dynamic Digital Product Passport (DPP), Material Volume Estimation (MVE), Supply Chain Optimisation (SCO), and Life Cycle Assessment (LCA), all fit into one modular and scalable ecosystem. In the report, system architecture and design principles with their corresponding technology stack, use case coverage, and interface mock-ups of system functionalities, supporting data-driven decision-making, circularity, and traceability throughout the value chain are being presented.

Achieved user-centred UI/UX, secure data flow, and safe integration frameworks enable monitored data approaches in real-time with pre-defined performance indicators for stakeholder engagement. All preliminary documentation and development of functionalities have been achieved, enabling full deployment and validation by the end of the second reporting period.

10.2. IMPACT ON THE W2W PROJECT

The platform's development is core to the strategy that W2W implements to valorise the construction and demolition waste as secondary wood materials. Vertical project objectives such as technological and data innovation, environmental impact, as well as stakeholder engagement, are all crucial to the platform's capabilities on complete capture and traceability, optimisation, and sustainability appraisal. This will demonstrate circular economy potential in the wood industry value chain enabled through digital transformation. Furthermore, the modular architecture of the platform will enhance versatility beyond W2W for wider industrial relevance and adoption.

10.3. FINAL REFLECTIONS AND RECOMMENDATIONS

The majority of milestones were addressed; however, there are a few in-progress aspects that will need attention during the next implementation phase. These aspects include tools merging validation, user testing external scans, user feedback interface modifications, and benchmarking system performance against real-world scenarios.

Consortium members should keep on being involved with the coordination of technical partners to complete the remaining components and ensure that shifting requirements from end-users are still being addressed. Focusing on these factors is critical for creating long-term sustainability and impact of the platform: continued and future usability, scalability, and openness.

11. ANNEXES

11.1. ANNEX I

Task	Business Requirements			
	ID	**Requirement Name and Description**	**Priority / Importance**	**Acceptance Criteria**
	Give each business requirement a unique ID. Link to other sheets	*Business requirements regarding features, functions, conditions, or capabilities as mentioned in the requirement gathering tasks and project deliverables.*	*MoSCoW Prioritisation Categories:* *M (Must have)* *S (Should have)* *C (Could have)* *W (Will not have)*	*Acceptance criteria represent a specific and defined list of conditions that need to be met before a requirement can be considered completed*
T13.1	b1	**Data Interoperability**: Ensure that different manufacturing systems (CAD/CAM, ERP) can effectively exchange data.	M	**EXAMPLE**: Data from various systems can be exchanged seamlessly without errors, and a standard interface for data import/export is implemented and tested across 3 different system types.
T13.1	b2	**Standardisation**: Develop standard interfaces and protocols for consistent data sharing across the entire supply chain.	M	**EXAMPLE**: A documented and tested interface protocol that complies with industry standards, with at least two systems successfully integrating.
T13.1	b3	**Real-time Tracing**: The DPP should support real-time tracing of wood waste materials across different stages.	S	**EXAMPLE**: The tracing system can track the location and status of materials within a 5-second delay for 90% of use cases.

T13.1	b4	**Explainable AI**: The DPP should use Explainable AI to provide understandable and actionable insights.	M	**EXAMPLE**: The AI models offer clear, interpretable outputs, and stakeholders can make decisions based on insights, confirmed by a user satisfaction score of 80% in testing.
T13.1	b5	**Data Security**: Ensure data integrity and privacy.	M	**EXAMPLE**: Security features meet GDPR standards and industry best practices; the system passes penetration testing with no critical vulnerabilities.
T13.1	b6	**User-friendly Interface**: The platform must be easy to use for non-technical users.	S	**EXAMPLE**: User testing shows that at least 90% of non-technical users can complete key tasks (data entry, data retrieval) with minimal guidance.
T13.2	b7	**Accuracy in Volume Estimation**: Algorithms must provide reliable and accurate estimates of the CDW volume.	M	Volume estimation algorithm has an accuracy rate of 95% when tested on various CDW in the form of point-cloud in las format. The point-cloud is expected to contain one or multiple CDW stockpiles with surrounding flat (near-zero slope) ground.
T13.2	b8	**Integration with DPP**: The estimated material volume should integrate with the DPP.	M	Volume data is automatically transferred to the DPP, confirmed by end-to-end testing of the integration.

T13.2	b9	**Multi-source Data Collection:** Develop tools to generate/acquire data for the two pipelines concerning this task, namely the volume estimation and the material recognition. Data acquisition refers to obtaining 3D point clouds (LiDAR-based or via drone-photogrammetry) for tuning the volume estimation pipeline, and/or 2D images from RGB cameras with proper annotations of CDW for training the material recognition algorithm.	M	Data collection tools are operational in real-world environments, and the collected data is suitable for volume estimation and material recognition.
T13.2	b10	**Ease of Use for Workers**: Provide an easy-to-use interface for site workers.	S	Workers complete key actions (taking photos, uploading data, annotating CDW/stockpiles, annotating materials on CDW surface, etc.) with minimal training, and surveys report ease-of-use.
T13.2	b11	**Material Detection**: Use deep learning based object detection algorithms for accurate material detection (classification + localisation).	S	The object detection model identifies "wood" and "glass" in CDW stockpiles. The greater the volume of the properly annotated data, the greater the accuracy rate of the model.
T13.3	b12	**Supply Chain Visibility**: Provide real-time tracking and status updates on secondary materials.	M	Provide 95% accuracy in real-time tracking of secondary materials' location and status

				during transport and storage, verified via system testing through pilots.
T13.3	b13	**Cost-Effective Supply Chain Design**: The tool should allow users to simulate and identify the most efficient supply chain configurations.	M	Simulations should identify at least a 10% reduction in logistics costs compared to baseline scenarios, validated through comparative analysis baseline scenario vs. achieved scenario.
T13.3	b14	**Inventory Management**: Optimise inventory levels of secondary materials to meet demand while minimising costs.	M	Optimise inventory levels to maintain safe inventory when necessary while reducing holding costs by 5%, tested over three operational cycles in project pilots.
T13.3	b15	**Scenario Simulation**: The tool should simulate various what-if scenarios for supply chain bottlenecks.	M	Simulate at least 3 distinct operational scenarios per pilot, each with complete data visualisation and actionable insights, evaluated and accepted for usability by the pilots.
T13.3	b16	**Optimisation of Logistics**: Improve routing, scheduling, and carrier selection.	M	Transportation costs are reduced by at least 10% and time savings are confirmed through simulated routes, validated via appropriate user testing or data benchmarks.
T13.3	b17	**Dynamic Demand Forecasting**: The tool should incorporate	S	Predict demand fluctuations within a 15% error margin

		predictive models to forecast fluctuating demand for recycled wood materials across different regions and timeframes.		based on historical and real-time market data. Validate accuracy over three forecasting cycles with varying scenarios.
T13.3	b18	**Eco-Impact Optimisation: Include metrics to assess and minimise** the environmental impact of supply chain activities, such as CO2 emissions from transportation.	C	Report environmental impacts (e.g., CO2 emissions) for all supply chain routes and suggest alternatives reducing emissions by at least 10% compared to the baseline.
T13.3	b19	**Risk Mitigation in Supply Chains**: Develop risk assessment tools to identify and mitigate potential disruptions (e.g., supplier delays, resource shortages).	C	Implement mitigation strategies that reduce the impact of supply chain disruptions by at least 15%, evaluated through simulations comparing scenarios with and without these strategies.
T13.4	b20	**Sustainability Assessment**: The tool can integrate LCA, LCC, SLCA input data and provide suitable impact assessment results and predictions for specific scenarios to users.	M	**EXAMPLE**: The tool integrates data derived from studies on Life Cycle Assessment (LCA), Life Cycle Cost Analysis (LCCA), and Social Life Cycle Assessment (S-LCA) for different possible scenarios related to further uses of wood products and their materials
T13.4	b21	**Compliance with standards**: Ensure studies follow ISO 14040 and 14044 standards, and data follow relevant LCA data models.	M	**EXAMPLE**: The LCA, LCC, SLCA studies comply with relevant ISO standards, such as ISO 14040 and ISO 14044 standards. Data

				will be collected and documented according to well-known LCA data models.
T13.4	b22	**Data Integration from other W2W tools**: LCA, LCCA, and S-LCA studies will consider data input from the Digital Product Passport and other relevant tasks in the project.	C	**EXAMPLE**: During the phase of collecting the life cycle inventory, relevant data from other WP13 tasks will be taken into consideration based on their relevance for the completion of the LCA studies.
T13.4	b23	**Real-time collaboration for data aquisition**: Support analysts and users on data inventory collection and process diagram creation.	M	**EXAMPLE**: Upon initiating the creation of a life cycle inventory, analysts and users will collaborate to jointly define and model the processes to be studied and collect all the necessary data
T13.4	b24	**Integrated library:** Allow analysts to create and manage an integrated document and template library to centralise access to resources and past studies.	C	**EXAMPLE**: As a very first step in a LCA study, the analyst visits the integrated library to locate resources like templates and helpful documents for guidance
T13.4	b25	**Centralised project management**: Allow analysts to initiate and manage LCA studies for a specific user/pilot and relevant product systems.	M	**EXAMPLE**: Analysts can create and manage studies for a specific user/pilot, under which all the relevant information is gathered, such as life cycle inventories, impact assessment results, visualisations, etc.

T13.4	b26	**Machine Learning**: Use machine learning/AI to improve the quality of data for the inventory and address gaps, and assist with the robustness of LCA results.	S	**EXAMPLE**: Intelligent features can assist each defined user role (e.g. analyst or pilot) in different ways, such as during the data collection stage or to provide insights on the final LCA results.
T13.4	b27	**Data Visualisation and Reporting: The tool will support data visualisation** and reporting capabilities to present LCA results and various insights to users.	M	**EXAMPLE**: The tool allows users to explore LCA results through interactive dashboards, plots and reports
T13.4	b28	**User Authentication and Authorisation: The platform must implement secure user authentication and authorisation** mechanisms to control access to features and data.	M	**EXAMPLE:** The system will support various user roles, such as analyst, pilot, and admin, each having access to specific features and data.
T13.4	b29	**User-friendly Interface**: Ensure the tool is easy to use and understandable to non-expert users.	S	**EXAMPLE**: The tool is easy to navigate, and all users understand the provided outputs
T13.4	b30	**Role-based access**: Ensure that users can perform specific actions or access certain parts of the system based on their assigned roles (i.e. user or analyst).	M	**EXAMPLE:** A model where permissions are assigned to roles, and users are assigned to those roles, defining what they can and cannot do in the system
T13.4	b31	**Handoff to and from LCA software**: The tool allows data transfer between the system and OpenLCA, enabling efficient	S	**EXAMPLE**: LCA analysts can export and import data to and from the tool to external LCA software for further analysis.

		inventory and result integration.		
T13.5	b32	**Interoperacustomisable**re seamless integration of all tools (DPP, supply chain, LCA, volume estimation).	M	The platform integrates all developed tools with a unified interface.
T13.5	b35	**User-friendly Interface**: The platform must be intuitive for all users, including recyclers, public authorities, and operators.	M	**EXAMPLE**: User testing shows 85% of users can operate the platform effectively after an initial training session.
T13.5	b36	**Collaboration and Knowledge Sharing**: Facilitate communication between stakeholders for data and best practice sharing.	S	**EXAMPLE**: Users confirm that collaboration features (forums, document sharing) improve communication with a satisfaction score of 80%.
T13.5	b37	**Flexible Deployment**: Ensure compatibility with various operating systems and hardware environments.	S	The platform runs on Linux-based and Windows systems without major performance issues, as confirmed by pilot testing.
T13.5	b38	**Training and Knowledge Exchange**: Provide built-in training modules to upskill users in circular wood upcycling.	C	**EXAMPLE**:70% of users report increased knowledge after using the built-in training materials.
T13.5	b39	**User Authentication and Authorisation: The platform must implement secure user authentication and authorisation** mechanisms to control access to features and data.	M	The system must require users to authenticate with a username and password or other multi-factor authentication methods (e.g., email verification).

				Different user roles must be supported, such as admin, operator, and stakeholder, each having access only to specific features.
				Access to sensitive data is restricted based on user roles, and unauthorised access attempts are logged.
				At least 95% of users are able to log in without issues during the initial rollout.
				The platform shows a successful login rate of 99% and a correct authorisation of users to the respective roles.
T13.5	b40	**User Profile Management**: The platform must provide functionality for users to create, view, edit, and manage their profiles.	M	Users can create, edit, and delete their profiles with at least 90% accuracy (i.e., without errors or loss of data).
				Profiles must store key information such as username, email, role, and preferences, which are saved and retrieved accurately.
				Users must be able to update their profile details without requiring technical support in 95% of cases.
				Admins can view and manage profiles of all users, including the

				ability to reset passwords and revoke access.
T13.5	b41	**Dashboard and User Interface**: The platform should feature a centralised dashboard that serves as the main entry point for users. The dashboard design should be user-friendly and customizable, allowing users to arrange and prioritise the display of information according to their preferences and needs.	M	The dashboard provides access to all core functionalities (e.g., data visualisation, notifications) and allows users to personalise the layout based on their preferences.
T13.5	b42	**Data Visualisation and Reporting: The platform must support data visualisation** and reporting capabilities to present insights and trends to users.	M	The platform provides visual reports (e.g., charts, graphs) on key data trends with at least 90% accuracy based on the data collected.
				Users can generate reports by selecting parameters (e.g., date range, material type) and exporting them in at least 3 formats (PDF, CSV, Excel).
				The reporting function allows users to schedule automated reports and receive them at specified intervals (e.g., daily, weekly).
				At least 95% of users can generate a report without technical support.

T13.5	b43	**Notifications and Alerts**: The platform must deliver notifications and alerts to users to keep them informed of important events and updates.	C	Notifications are delivered to users via the dashboard and email within 10 seconds of an event trigger (e.g., new data entry, system update).
T13.5	b44	**Search and Filtering**: The platform must include robust search and filtering functionality to help users find relevant content and data.	M	The search functionality retrieves relevant data within 3 seconds of entering a query. 90% of test users are able to find relevant data without technical support using the search and filtering tools.
T13.5	b45	**Support for End-Users and Stakeholders**: The platform should support the tasks of end-users, including operators, formulators, recyclers, public authorities, and standardisation actors. It should facilitate interactions, communication, and coordination among stakeholders along the supply chain.	S	Stakeholders can log into the system and access their respective data and tools with role-based access control, confirmed by testing with a 90% success rate.

12. REFERENCES

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