WOOD2WOOD

A Wood-to-Wood Cascade Upcycling Valorisation Approach

» Deliverable 13.4

Life cycle analysis computation tool (version 1)

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Project Website	In progress

PROJECT INFORMATION

REVISION AND HISTORY CHART

Version	Date	Author	Description of changes
0.1	22/04/2025	DRAXIS	ToC
0.2	02/06/2025	DRAXIS	Draft version for internal review
0.3	10/06/2025	eBOS, CERTH	Reviewer comments
1.0	23/06/2025	DRAXIS	Submitted version to the consortium
2.0			Revised submitted version (if required)

Dissemination Level		
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
FU	Functional Unit
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCSA	Life Cycle Sustainability Assessment
ML	Machine Learning
QA	Quality Assurance
RBAC	Role-Based Access Control
S-LCA	Social Life Cycle Assessment
SSO	Single Sign-On
UC	Use Case
W2W	Wood2Wood

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EXECUTIVE SUMMARY

Deliverable D13.4 provides an overview of the Version 1 of the Wood2Wood (W2W) Life Cycle Sustainability Assessment (LCSA) tool, developed under Task 13.4. This tool supports the broader objectives of the W2W project by enabling multi-dimensional sustainability assessment of cascade valorisation pathways for wood materials. The deliverable offers a comprehensive description of the tool's design, functional capabilities, technical architecture, and validation activities.

The W2W LCSA tool will support the work of conducting studies on Life Cycle Assessment (LCA), Life Cycle Cost Analysis (LCCA), and Social Life Cycle Assessment (S-LCA) for the project use cases and for different possible scenarios that make use of the project technologies. Specifically, the tool will:

- **Support project partners** in conducting sustainability assessments for various process chains (e.g. pollutant-free wood recovery, biocomposite materials, nutrient extraction).
- **Enable comparison of alternative cascade paths** based on wood type, treatment processes, transport options, and end-of-life scenarios.
- **Identify environmental, economic and social "hot spots"** where process changes can lead to the greatest sustainability gains.
- **Facilitate collaborative data collection and process modelling between LCA analysts and stakeholders** through structured templates and interactive diagrams, allowing definition, refinement, and validation of the system boundaries, inputs, and outputs.
- **Provide import/export capability with external LCA software** for model computation and allow import of results for visualisation and reporting.
- **Support stakeholders and decision-makers by visualising results** generated from external LCA software tools to inform decisions.
- **Generate structured, editable reports** to support internal evaluation, decision-making and stakeholder communication.

In Version 1, the functional requirements of the tool were defined based on internationally recognised sustainability assessment standards, particularly those defined by ISO 14040:2006, which establishes the general principles and framework for conducting a LCA and ISO 14044:2006 which provides detailed requirements and guidelines for each phase of the LCA process, including goal and scope definition, inventory analysis, impact assessment, and interpretation.

Version 1 of the tool is iteratively improved based on partner feedback, with additional functionalities planned for future development. The experience gained through this release will feed into the specification and implementation of Version 2, to be delivered as D14.4, that will present the system architecture, target users and use cases, key features, screenshots and explanation of the user workflow. Version 2 will serve as the final, validated version of the tool ready for broad use within the project and potentially for external stakeholders.

1. INTRODUCTION

The W2W LCSA tool addresses key challenges in conducting sustainability assessments collaboratively across diverse stakeholders. It is designed to overcome common barriers such as communication inefficiencies, inconsistent data collection, and limited familiarity with LCSA methodologies. These issues often compromise the quality, clarity, and timeliness of sustainability evaluations in complex projects like W2W.

To mitigate these challenges, the tool focuses on improving two critical phases of the assessment process: goal and scope definition and Life Cycle Inventory (LCI) data collection. By refining these phases through structured templates and collaborative workflows, the tool enhances both the accuracy and efficiency of data gathering, while also ensuring that results are more accessible and interpretable for the users, including LCA analysts and stakeholders.

The W2W LCSA tool is being developed as a unified digital environment capable of supporting assessments across all three pillars of sustainability: environmental, economic, and social. The inventories built within the system can be analysed using the tool's internal calculation modules or exported for processing in external LCA software environments such as OpenLCA.

The W2W LCSA tool clearly addresses several key objectives of the project. It supports the validation of the sustainability performance of the designed framework based on techno-economic and Life Cycle Assessment considerations (KPI O1.4) and operationalises an LCA-based cascade assessment tool across the three targeted value chains (KPI O4.1). As part of the broader multi-digital interface platform, it contributes to the development of integrated digital services aimed at reaching a considerable community of active users by Month 48 (KPI O4.4). The tool also enables CO_2 emissions tracking aligned with the project's impact targets and supports the project goal of achieving a reduction in environmental impact compared to linear economy alternatives (KPI 7.2).

1.1. PURPOSE OF THE TOOL

Conducting comprehensive sustainability assessments using LCA methodologies is essential for evaluating the environmental impact of products and processes. These assessments follow internationally recognised standards, but their effective implementation requires precise goal definition, system modelling, and data collection, tasks that depend heavily on stakeholder input with limited expertise in sustainability analysis.

Existing commercial LCA tools offer advanced analytical capabilities but are primarily suited for LCA experts. This creates a significant barrier to participation for non-specialist stakeholders and complicates collaboration across project teams. As a result, LCA assessments and results often suffer from communication breakdowns, time inefficiencies, and reduced credibility. Conversely, simplified self-assessment tools typically offer high-level or CO_2-centric outputs, lack cross-sector flexibility, and fail to deliver comprehensive, multi-dimensional insights essential for informed decision-making in circular systems.

To address these limitations, the W2W LCSA tool combines expert-level capabilities with user-friendly guided workflows. The tool enables collaborative data collection through shared templates, including embedded process diagramming for intuitive system modelling. This bridges

the communication gap between LCA analysts and stakeholders, supporting structured collaboration.

The platform goes beyond impact calculation by integrating automated report generation, and visual dashboards that translate complex results into actionable insights. In addition, the tool supports import/export capabilities with external LCA tools such as OpenLCA, creating a unified environment for conducting environmental assessments in support of optimal wood cascade valorisation pathways.

1.2. Scope of Version 1

Version 1 allows LCA analysts and stakeholders to co-create and manage LCI data through customisable templates and real-time system diagrams. The tool provides a structured environment for documenting processes, inputs, and outputs.

Version 1 fully supports the export of LCI data in formats compatible with external tools such as OpenLCA. Upon completion of impact assessments using an external tool, LCA analysts can re-import results into the LCSA tool to enable post-processing. The platform supports the generation of interactive dashboards and automatically structured reports, including predefined visualisations and basic export options, facilitating the review and interpretation of results by stakeholders. The tool guides users through the entire assessment workflow, from study definition to data collection and reporting.

To enhance usability and knowledge reuse, the tool includes a centralised repository for LCA-related materials. This digital library allows LCA analysts to upload, organise, and retrieve datasets, project documentation, previous studies, and graphical assets. This repository is searchable by category and tag.

1.3. Timeline for Version 1

Action points and timeline for version 1 (M8 – M18) are included in the Table 1.

Table 1: Timeline of the first version of the W2W LCSA tool.

No.	Action	Duration	Months
1	Conduct design research, analysing both commercial and simplified platforms to identify how current tools support the core phases of LCA	1 month	M8
2	Define user and technical requirements for Version 1 based on findings from design research	1 month	M9
3	Create high-fidelity mock-ups for version 1	3 months	M10 - M12
4	Review and validation of mock-ups for version 1 with project partners via co-design sessions and presentations in project meetings	1 month	M13
5	Frontend + backend development of version 1	4 months	M14 – M17
6	Desk research related to the LCA studies of the projects' use cases	5 months	M14 – M18

7	Meetings with use case partners in the context of defining the Goal & Scope of the LCA studies	4 months	M14 – M17
8	Preliminary work for creating inventory templates for the LCA studies	5 months	M14 – M18
9	Internal QA testing & bug fixes	1 month	M17
10	Final adjustments & submission of D13.4	1 month	M18

2. PLATFORM OVERVIEW

This section outlines the key user groups the platform is intended for and the practical use cases it supports in real-world applications. These users interact through the platform to collect high-quality data, prepare for impact assessments, and interpret outcomes. The described use cases demonstrate how the tool enables frictionless collaboration, supports data quality and consistency. To support these use cases, the tool offers a range of key features in its first version to enhance usability and ensure reliable outcomes throughout the LCSA process.

2.1. TARGET USERS AND USE CASES

The W2W LCSA tool is designed to serve two primary user groups within the W2W project:

- **LCA analysts**: Technical users responsible for setting up and managing life cycle studies, collecting and validating data, running impact assessments, and preparing reports. In the context of W2W analysts are represented by DRAXIS as the responsible party for conducting the LCA studies for the use cases in the project.
- **Stakeholders**: In the context of W2W they are the use case partners who provide input data and engage with results. These users play a key role in validating the tool through real-world application in W2W's demonstration cases.

The tool addresses three core functional use cases that define its purpose and value:

i. **Collect LCI data from stakeholders**: The tool enables LCA analysts to collaboratively gather detailed LCI data from stakeholders through customisable, structured templates. This ensures consistent data capture across LCA studies and supports efficient communication between stakeholders throughout the data collection phase.

ii. **Conduct guided impact assessment preparation**: Users are supported through each phase of the LCA lifecycle with built-in guidance, helping them define product systems, enter LCI data, and prepare for external Environmental-LCA impact calculations. The tool ensures that all necessary inputs are validated and organised, enabling a smooth handoff to OpenLCA and reducing the risk of errors or incomplete assessments.

iii. **Generate and manage results for internal and stakeholder reporting**: Following impact analysis, the tool allows LCA analysts to import results, create interactive dashboards, and produce structured reports tailored for both internal evaluation and feedback to stakeholders. Stakeholders can consult their results and reports in the tool and propose new assessments, triggering a feedback loop.

2.2. KEY FEATURES FOR VERSION 1

The key features of the W2W LCSA tool for Version 1 are the following:

- Collaborative LCI data collection and management using structured templates
- Centralised library of LCA studies, papers, data or other relevant information
- Diagrams to collaboratively model process flows within product systems
- Support for Environmental-LCA with import - export functions to integrate with external LCA software
- Data visualisation and reporting for interpreting and communicating impact results
- In-app notifications to inform users of data requests and updates
- Data quality and validation checks to ensure completeness and consistency of collected data
- Authentication and authorisation features, including account management for role-based access control and user profile editing
- Integrated step-by-step guidance to lead the users through the entire LCSA process
- Automatic dashboard creation upon importing Environmental-LCA results

3. USER INTERFACE

The user interface of the W2W LCSA tool has been designed to support the full lifecycle of LCA within an intuitive and collaborative environment. The interface provides clear navigation, contextual guidance, and responsive elements that enhance the overall user experience. The layout and visual hierarchy are tailored to accommodate both LCA analysts and stakeholders, ensuring that each user can perform their tasks efficiently without requiring in-depth technical expertise.

Figure 1 presents the hierarchical structure of data and modelling within the W2W LCSA tool, progressing from process inputs to the full environmental study:

- **Study***:* At its highest (outermost) level, the LCA study encompasses the entire modelling effort, defining the study description and the environmental impacts of the product systems included.
- **Product Systems**: A product system integrates multiple processes to form a complete perspective on a product's creation, use, and eventual disposal.
- **Processes**: A process represents a discrete operation within the life cycle, consolidating various process inputs, outputs and equipment to represent a single activity.
- **Process Inputs, Process Outputs & Equipment***:* At the most detailed (innermost) level are the core data elements: the inputs (e.g., materials, energy), outputs (e.g., emissions, waste), and equipment used within one or more processes.

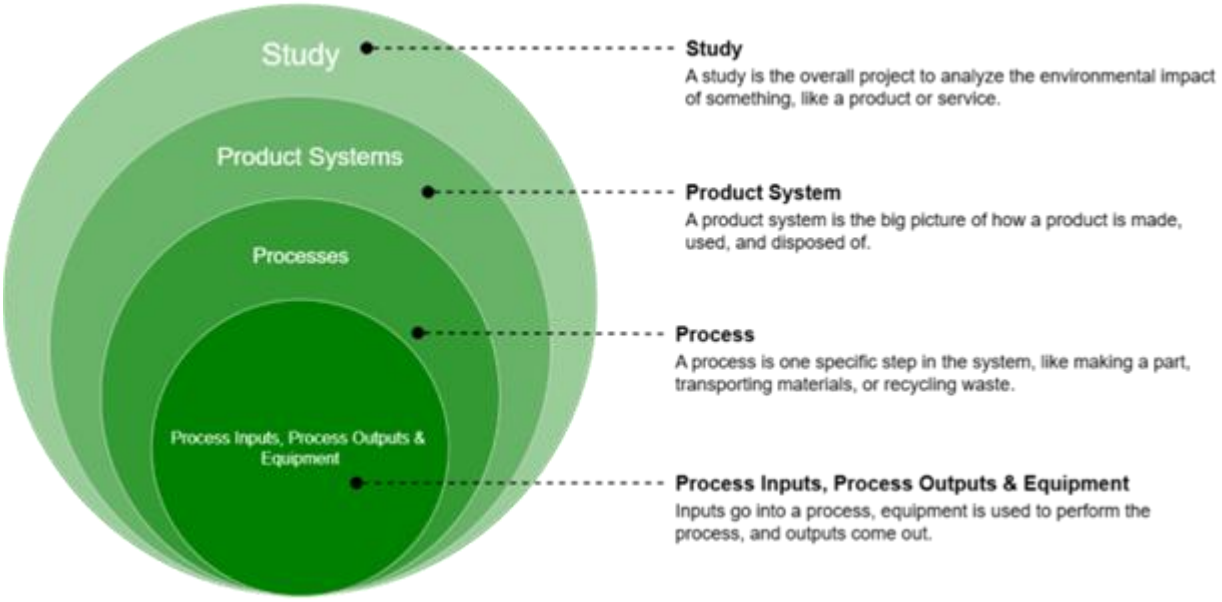

Figure 1: Hierarchical Structure of LCA Modelling of the LCSA tool.

3.1. NAVIGATION STRUCTURE

Once users log in, they are redirected to the Homepage, which provides an overview of all existing LCSA studies. From this page, users can access the following tabs:

- **Studies**: Browse, search, and filter studies using tags or keywords. Users can track recent activity, view recent edits, and LCA analysts can create new studies. Once a study is opened, the user is directed to a dedicated workspace organised into four main sections:
    - **Study Overview**: Provides a summary of the study's description. Users can manage study-level information and track the status of associated product systems, dashboards and reports.
    - **Product Systems**: Enables users to collaboratively build and manage product systems. LCA analysts and stakeholders can input LCI data, visualise flows through diagrams, and prepare structured models for export to OpenLCA.
    - **Dashboard Results**: Displays interactive visualisations of impact assessment results. LCA analysts can explore findings and create more custom graphs.
    - **Reports**: Allows LCA analysts to generate and manage structured reports summarising key findings. Reports can then be exported in PDF or DOCX format and are tailored for both internal use and stakeholder review.
- **LCA Library**: A centralised repository for storing and reusing study components, datasets, and references. Access to this tab is limited to LCA analysts.

Figure 2 presents the UI flow diagram of the main tool interface after user login, showing navigation between key pages such as the study overview, product system, results dashboard, and report generation, including integration points with external system, such as the OpenLCA tool. Figure 3 presents the flow diagram of the entire W2W LCSA tool, illustrating the sequence of user interactions and page transitions throughout the tool's interface.

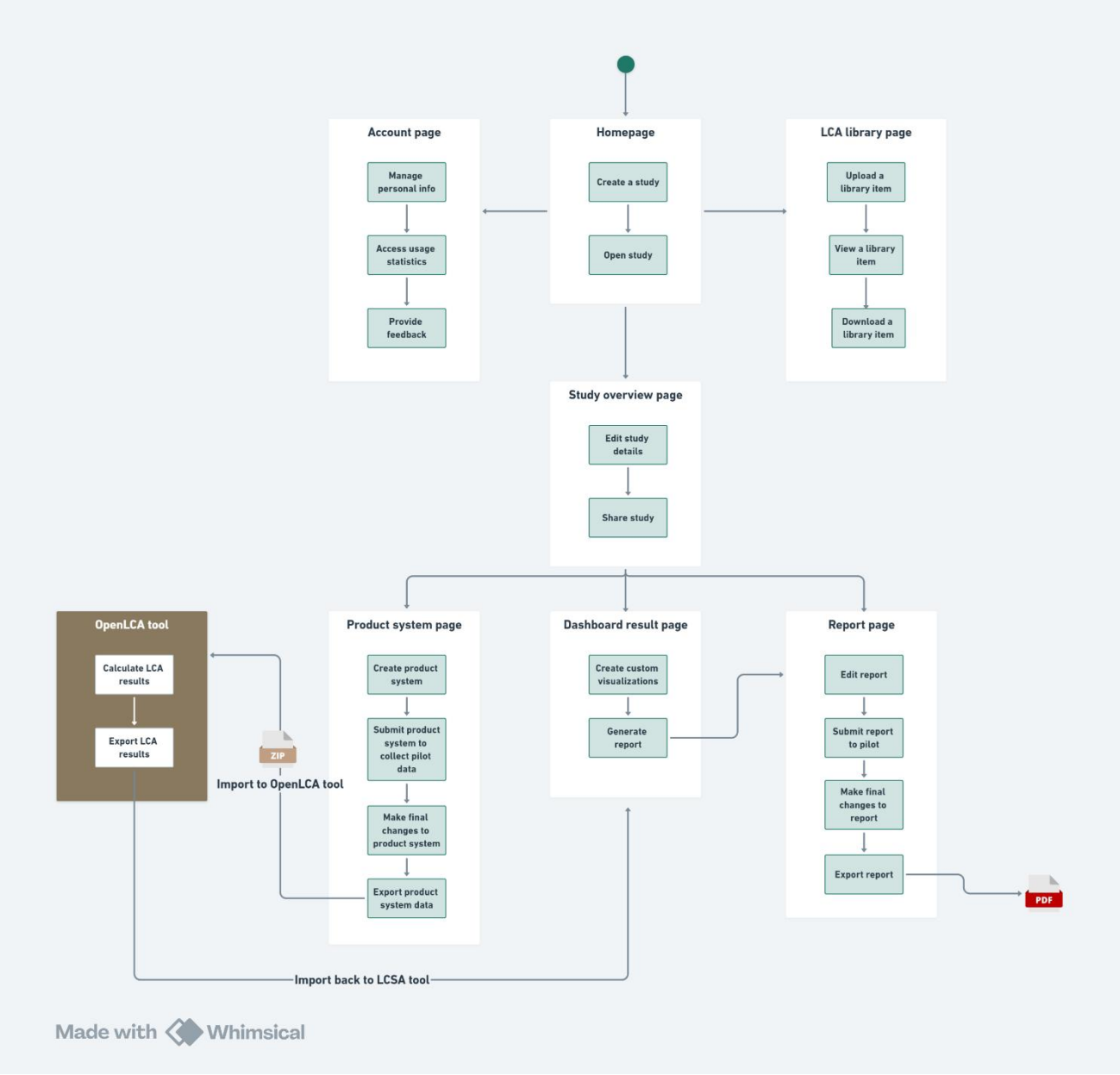

Figure 2: UI flow diagram of the main tool, once the user is logged in.

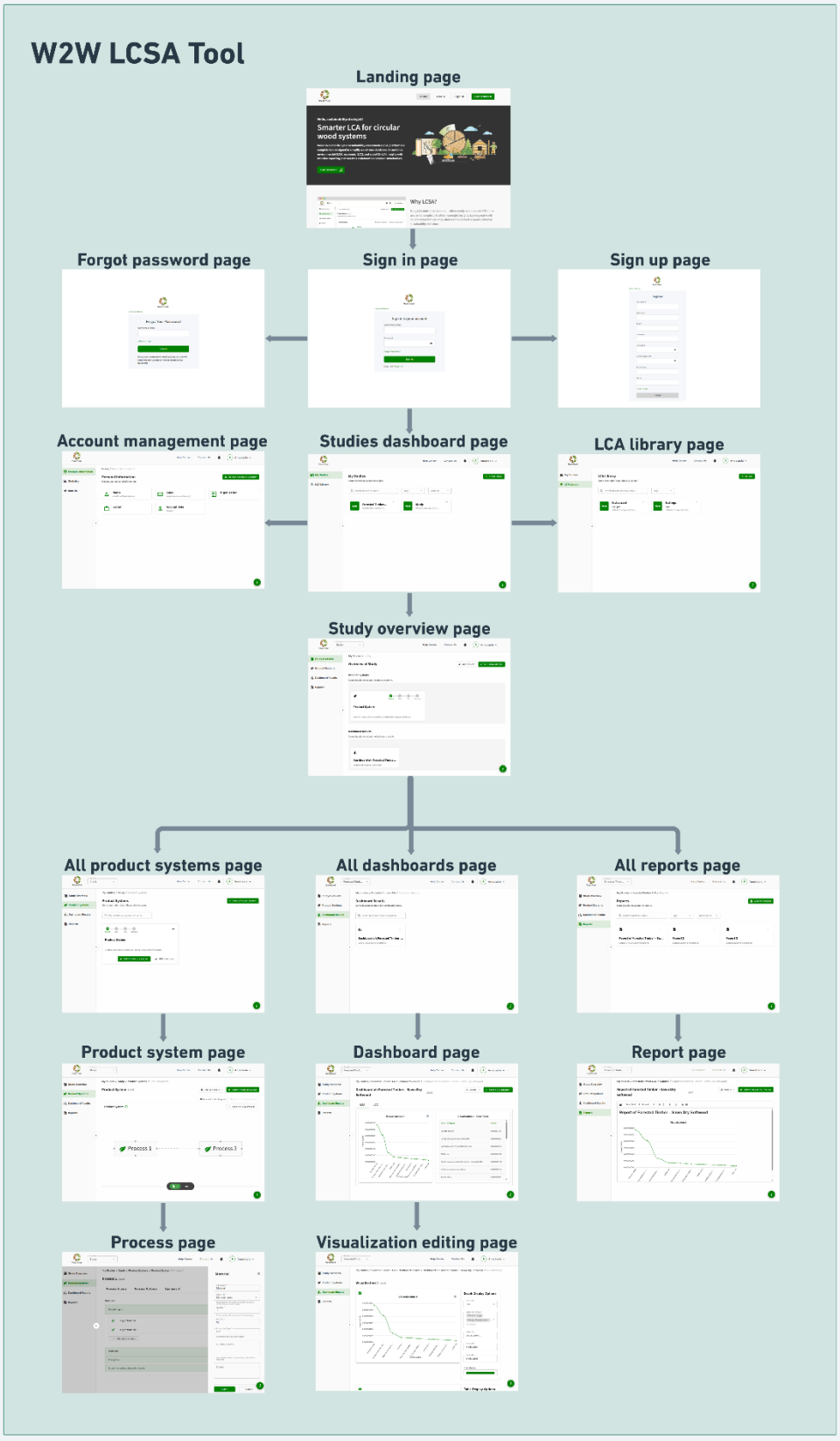

Figure 3: Flow diagram of the whole tool.

3.2. WORKFLOW

The main workflow of the tool is to conduct a full LCA study collaboratively, from study setup to reporting. To achieve this, the user should do the following procedures:

- Tool Access
- LCA Library Population (optional)
- Account Management and Feedback (optional)
- Study Setup and Management
- LCI Data Collection
- Results Visualisation and Report Generation

3.2.1. Tool Access

Users can access the tool via the following link: w2w.draxis.gr.

Unregistered users are redirected to the landing page (Figure 4), which provides an overview of the tool, detailing the challenges it addresses and showcasing its key features and benefits. From here, users can sign in (Figure 5) or create an account (Figure 6) to access the full functionality of the tool.

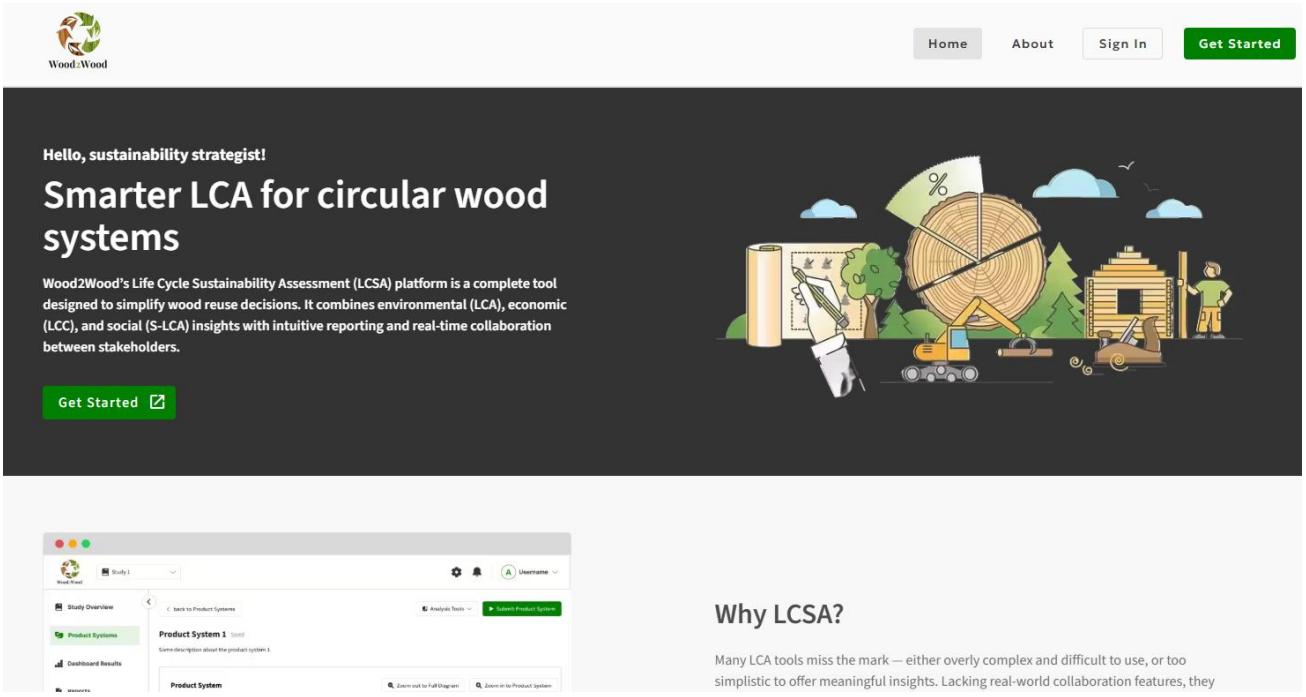

Figure 4: Landing page.

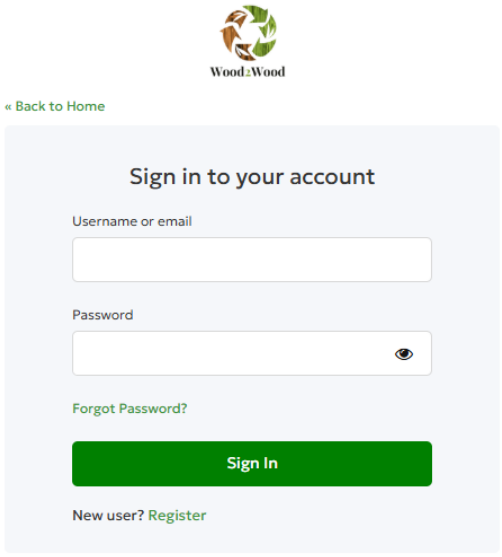

Figure 5: Sign in page.

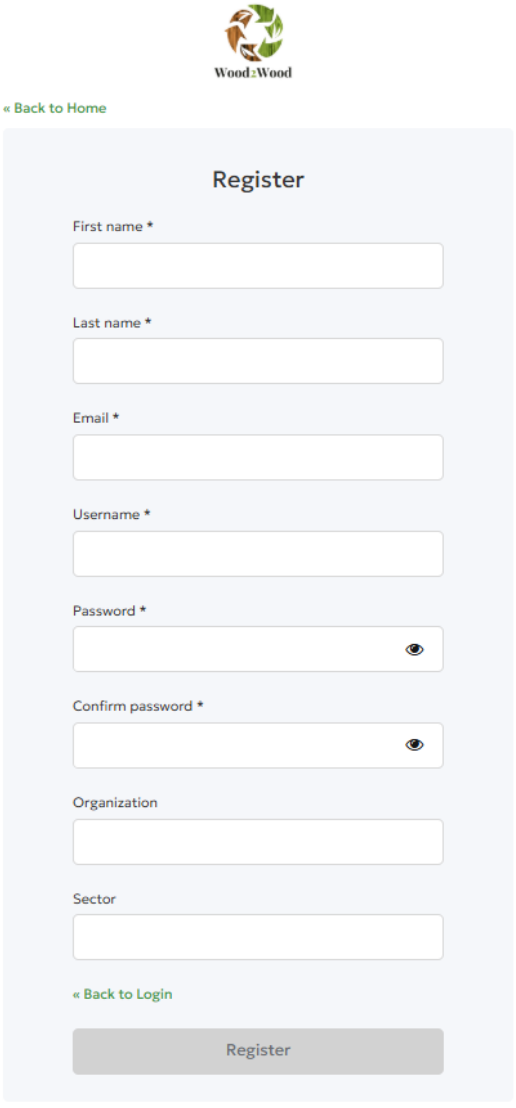

Figure 6: Sign up page.

3.2.2. LCA Library Population (optional)

The tool provides a centralised library (Figure 7) where LCA analysts can upload (Figure 8), access, and use datasets, visual content, and related documents. Studies are searchable by topic, tagged for easy navigation. Analysts can upload supporting materials in various formats, enabling a consistent and collaborative approach to sustainability analysis.

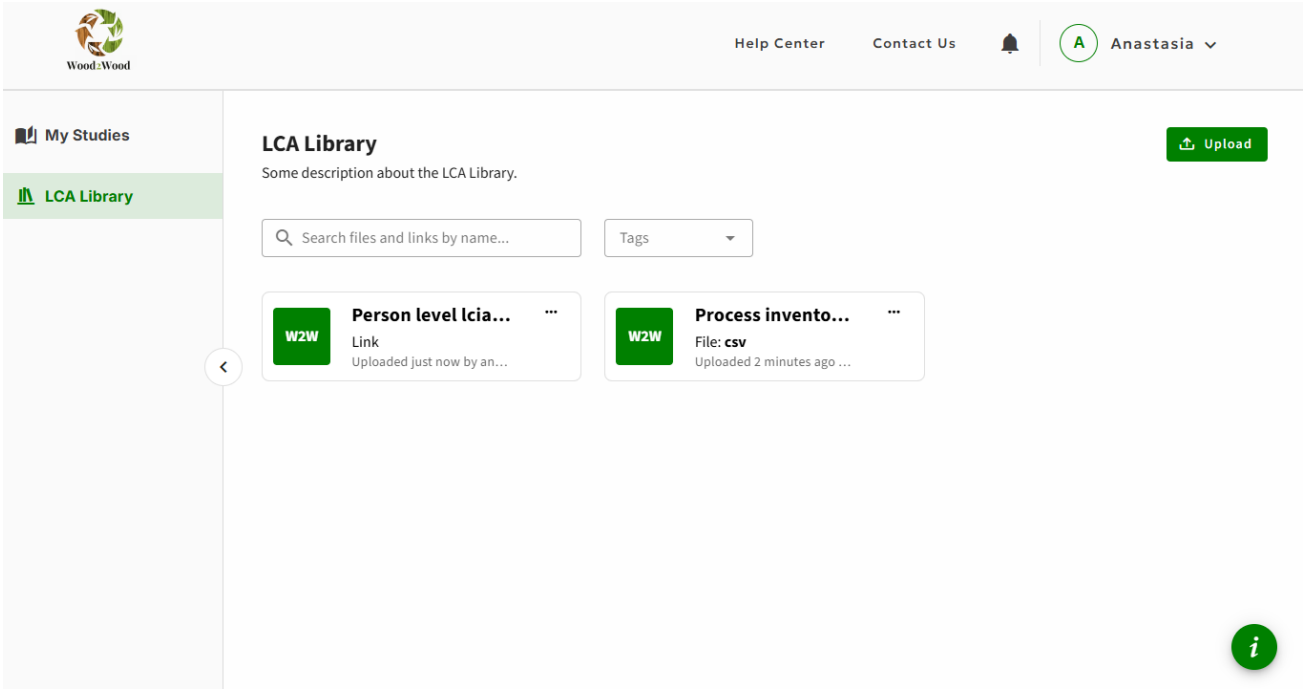

Figure 7: LCA library page.

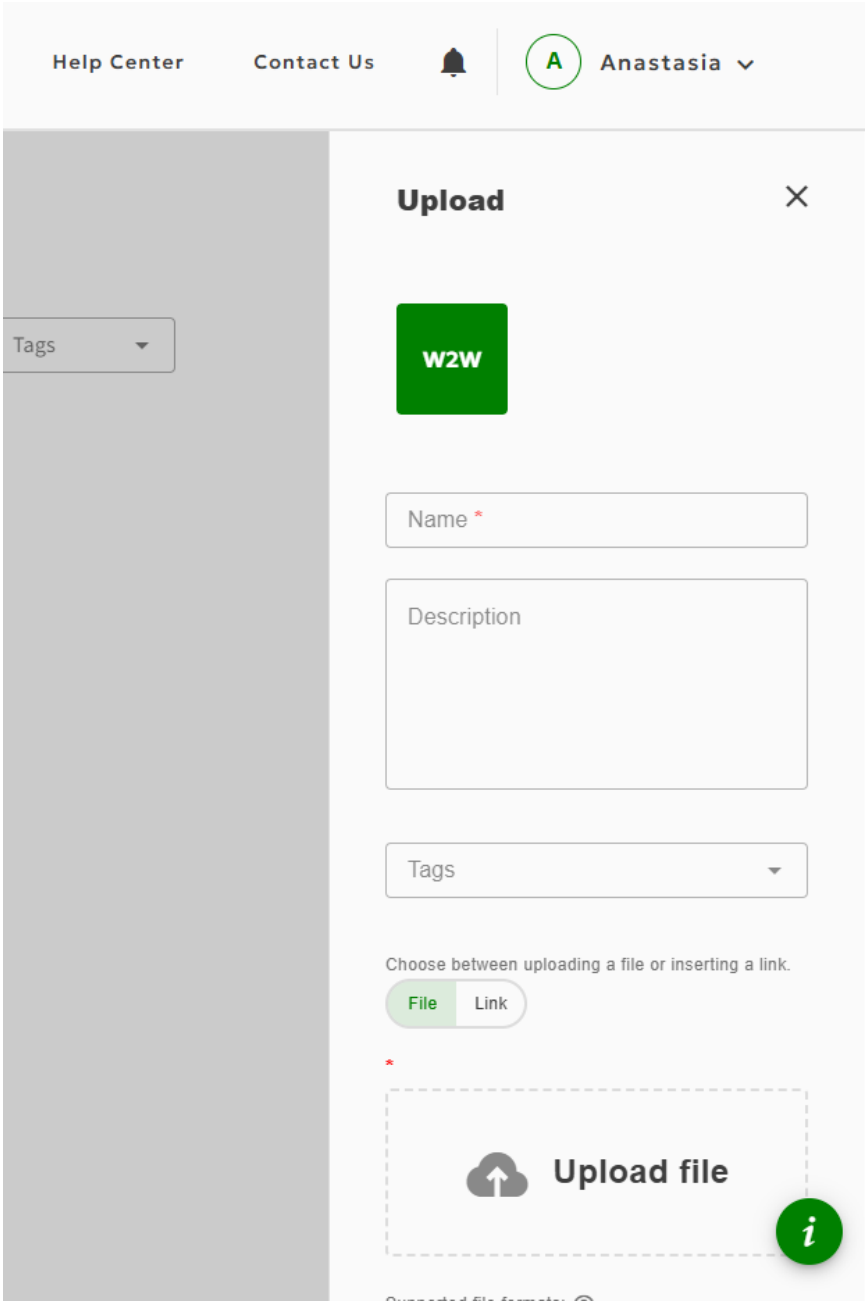

Figure 8: LCA items upload.

3.2.3. Account Management and Feedback (optional)

The Account Management page (Figure 9) allows users to customise and manage their personal workspace within the tool. In addition to updating basic account information, users can access usage statistics (Figure 10) and provide feedback to support continuous tool improvement (Figure 11).

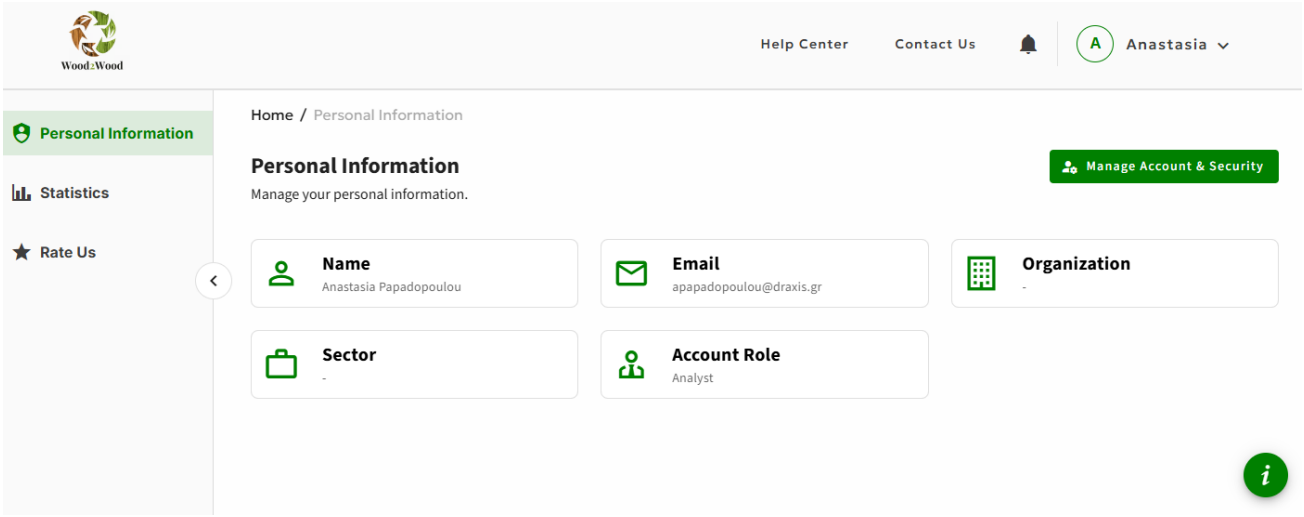

Figure 9: Account management page.

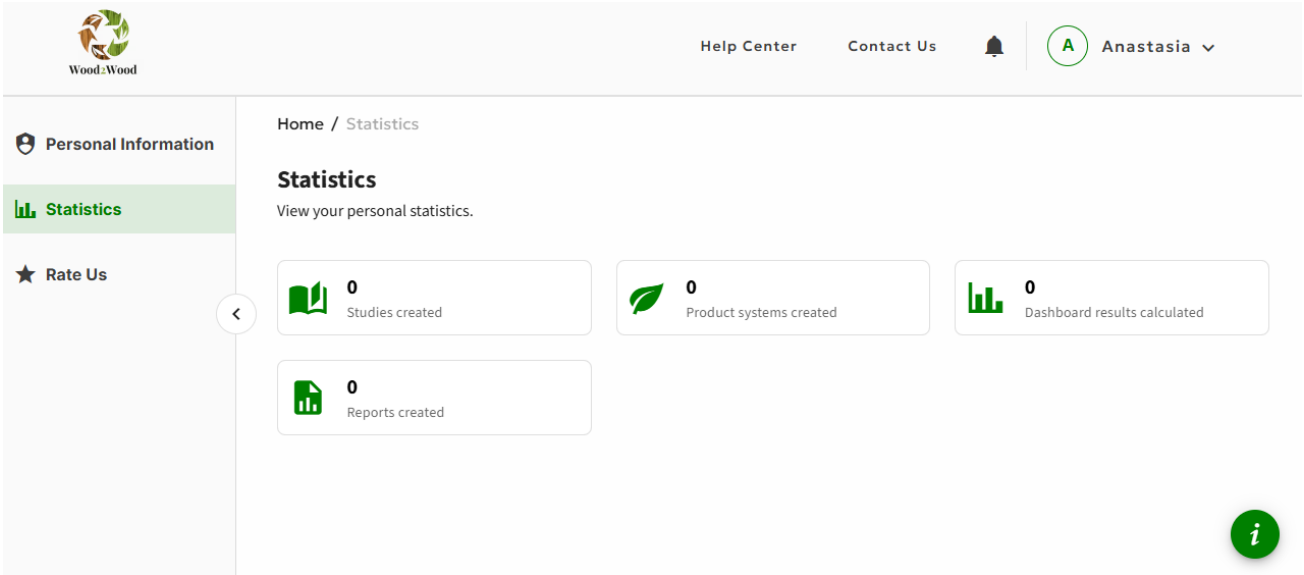

Figure 10: User statistics page.

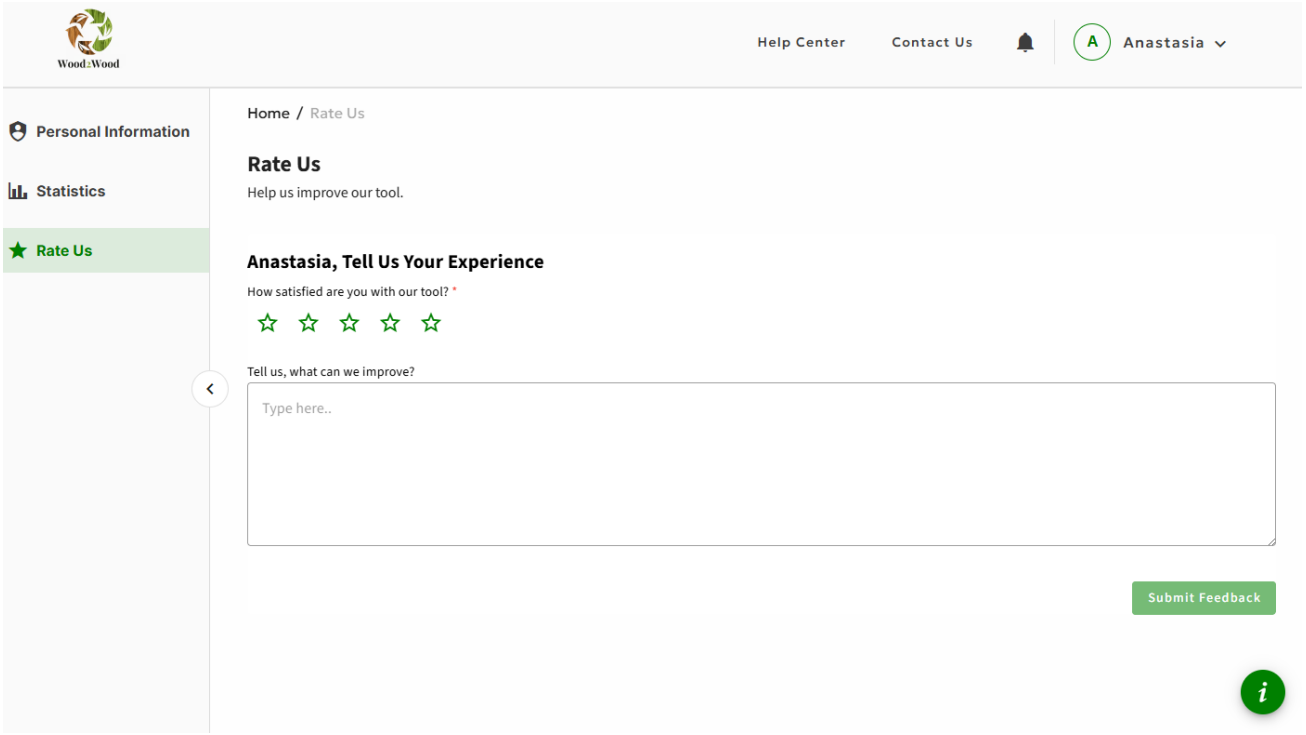

Figure 11: Feedback submission page.

3.2.4. Study Setup & Management

The tool provides a Studies Dashboard (Figure 12) where users can manage and access their research studies efficiently. The dashboard displays a grid of study cards, each showing key details such as the study name, last edited time, and the user who made the changes. Users can filter studies using search, tags, and visibility options to quickly locate specific studies, or create new ones (Figure 13).

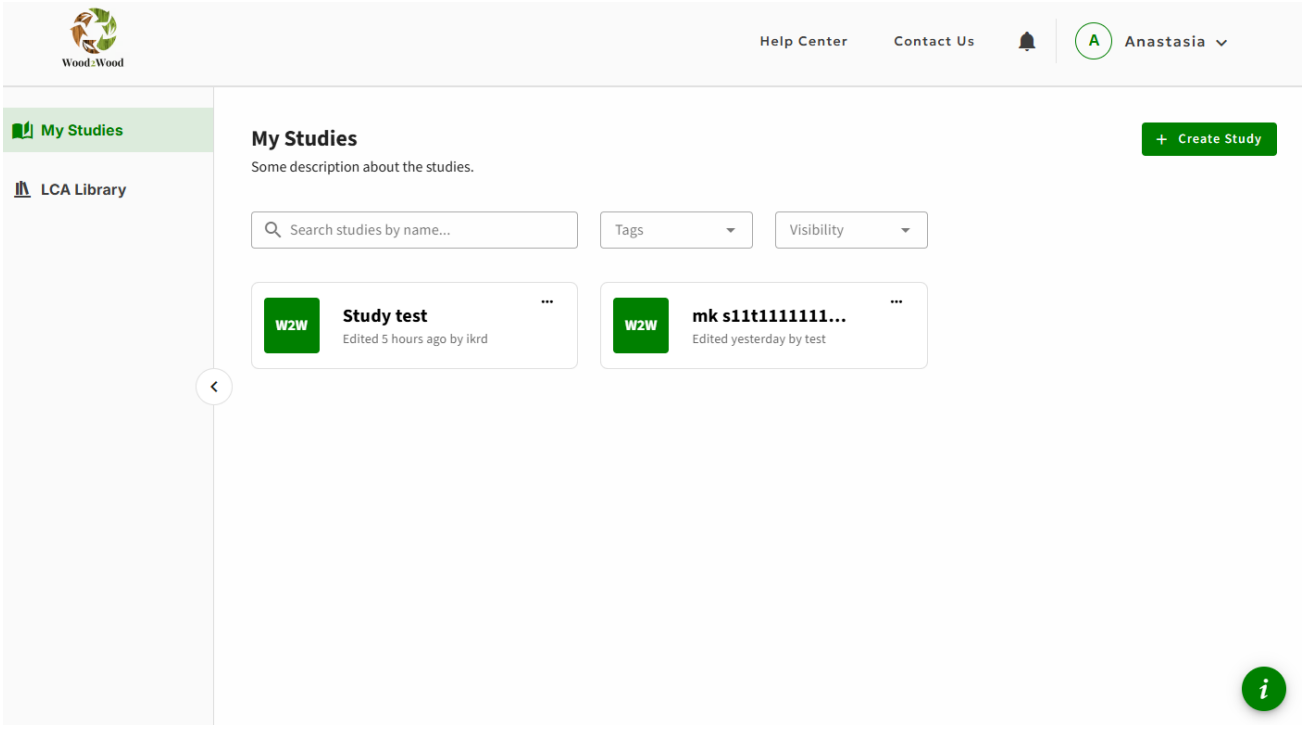

Figure 12: Studies dashboard page.

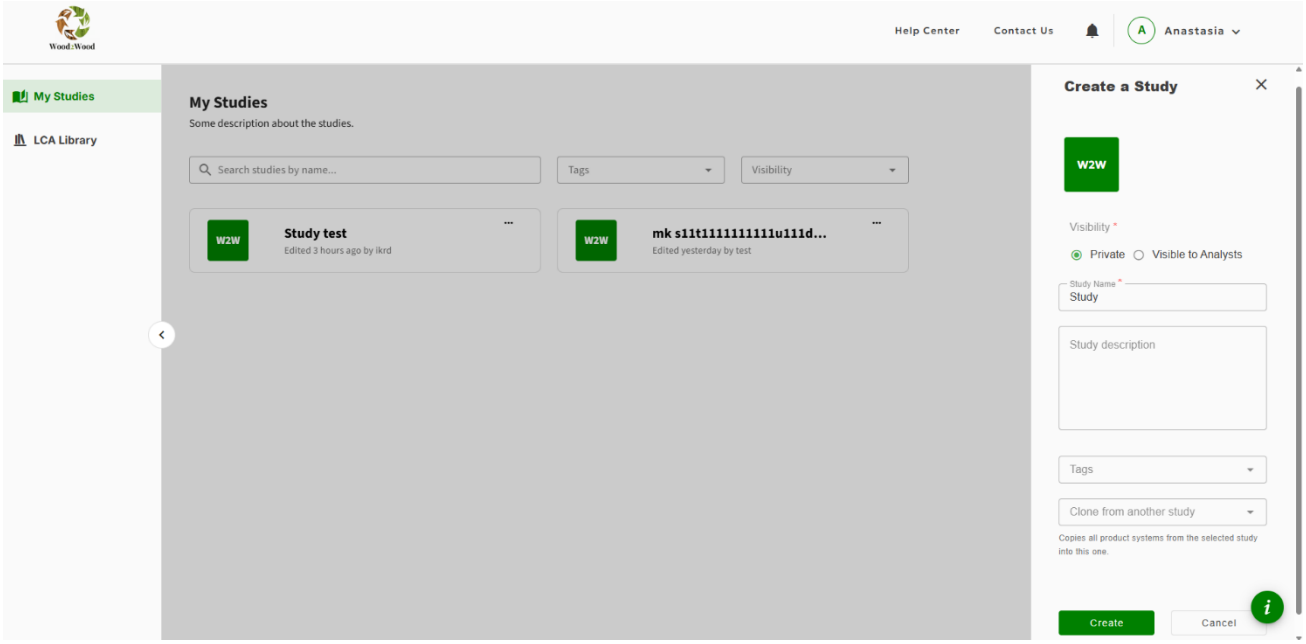

Figure 13: Study setup.

The tool provides a dedicated study workspace (Figure 14) where users can manage all components of an individual sustainability assessment in one place, guiding them step-by-step through the entire study workflow (Figure 15), offering prompts and recommended actions to complete each phase. Each study includes structured sections such as Study Overview, Product Systems, Dashboard Results, and Reports to support a clear and organised workflow. Users can track

progress, collaborate on system modelling, and view or edit study details in a centralised interface tailored for transparency and ease of use.

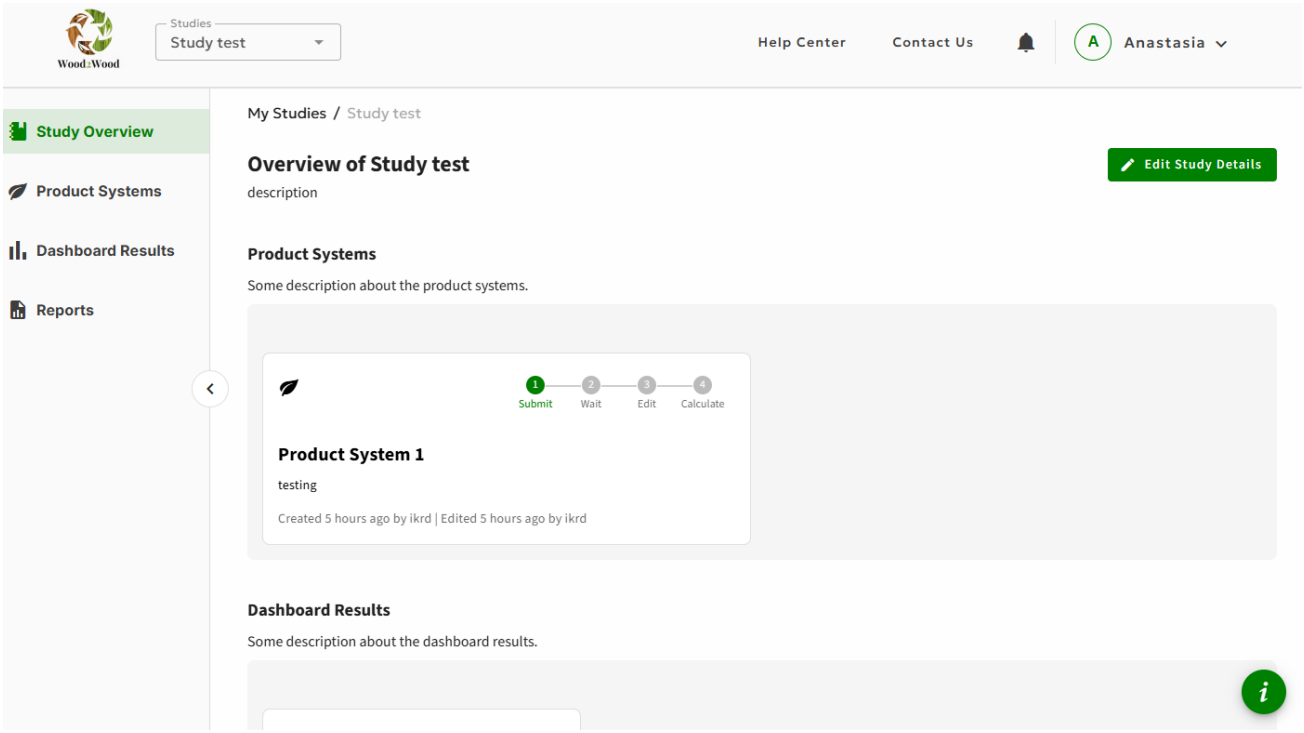

Figure 14: Study overview page.

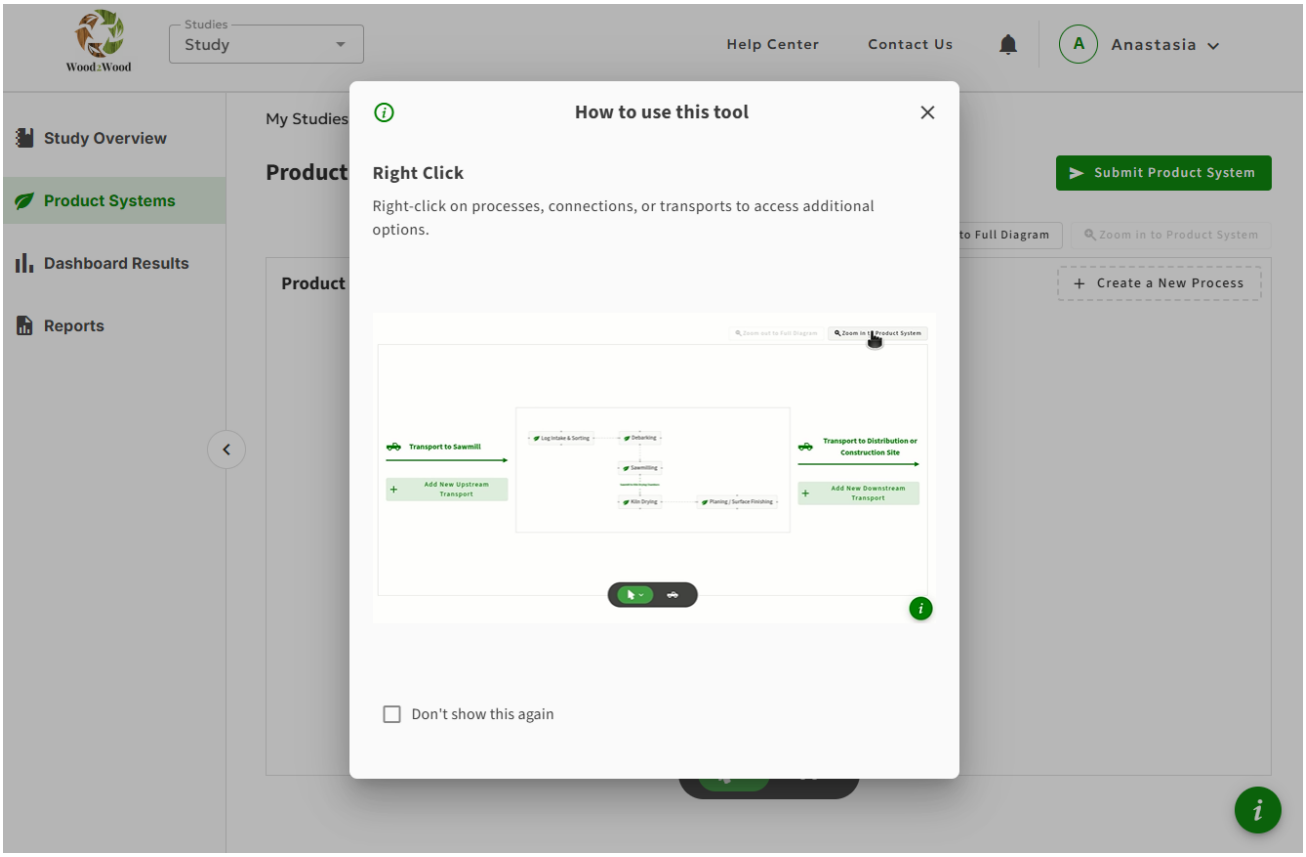

Figure 15: Integrated guidance for creating processes and establishing connections between them in diagram mode.

3.2.5. LCI Data Collection

The tool includes a collaborative LCI data collection and management through structured templates that combine diagramming (Figure 16 & Figure 17) and form-based inputs (Figure 18 - Figure 20). Users can add and connect processes (Table 2) using an intuitive, drag-and-drop interface, visualising the entire system as a flowchart. Diagrams can be edited in real-time or asynchronously, with all changes automatically synced and users notified (Figure 21), ensuring that models remain current and aligned.

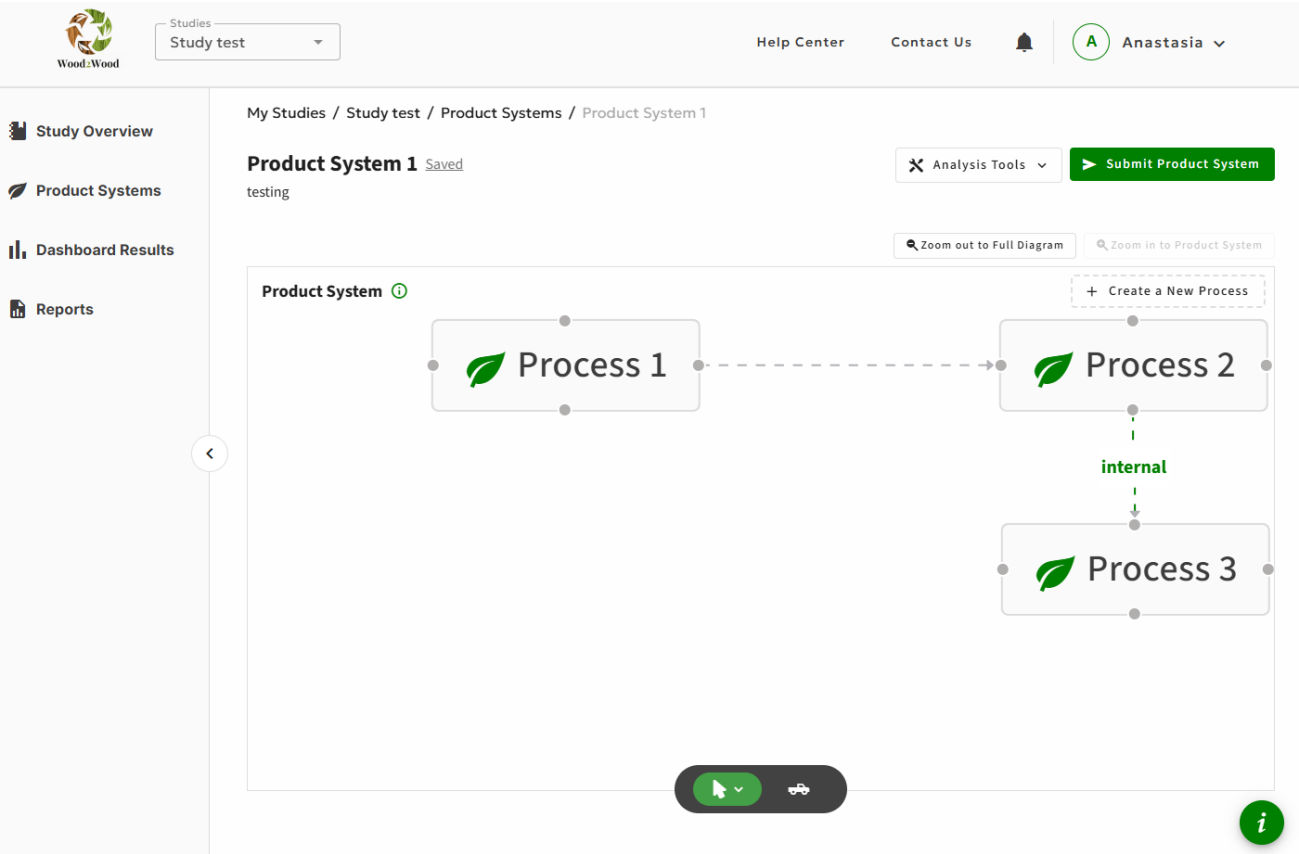

Figure 16: Product system diagram view (zoomed in).

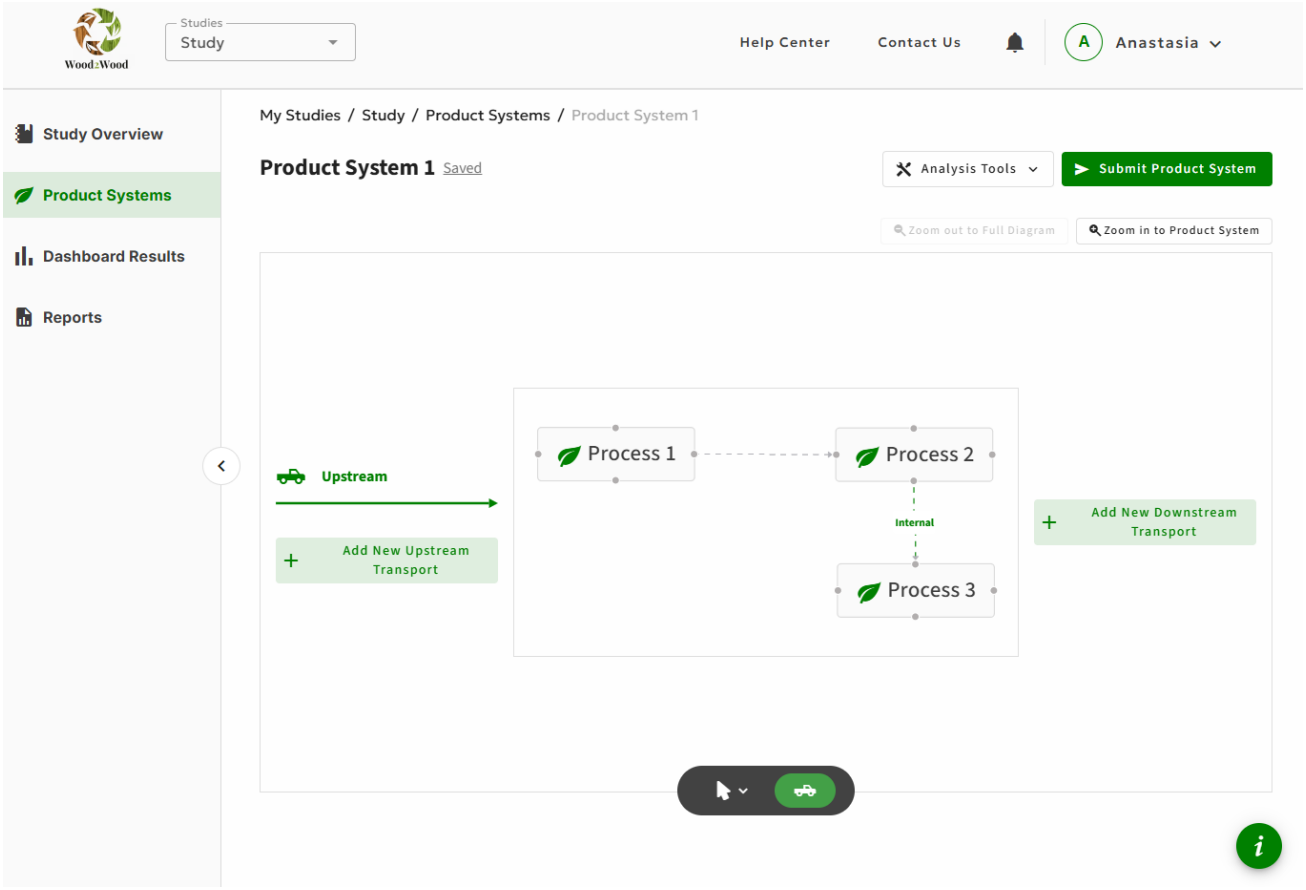

Figure 17: Full product system diagram view (zoomed out).

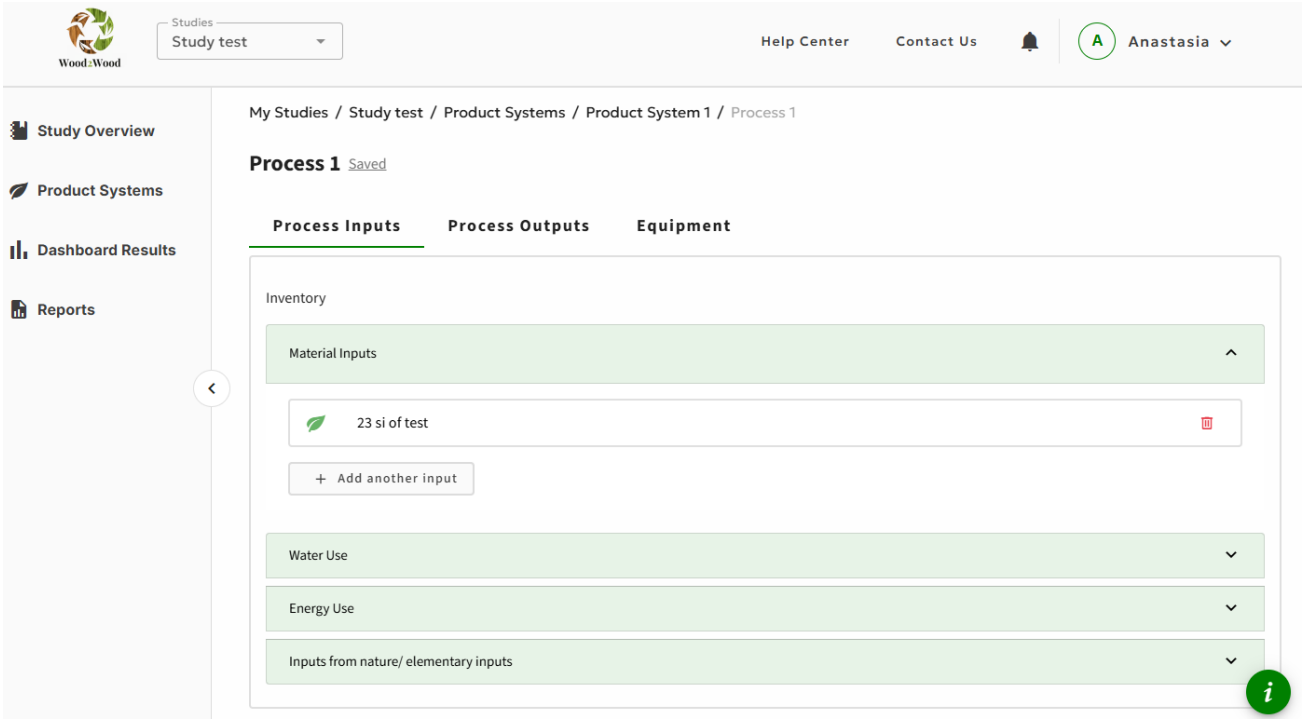

Figure 18: Process inputs page.

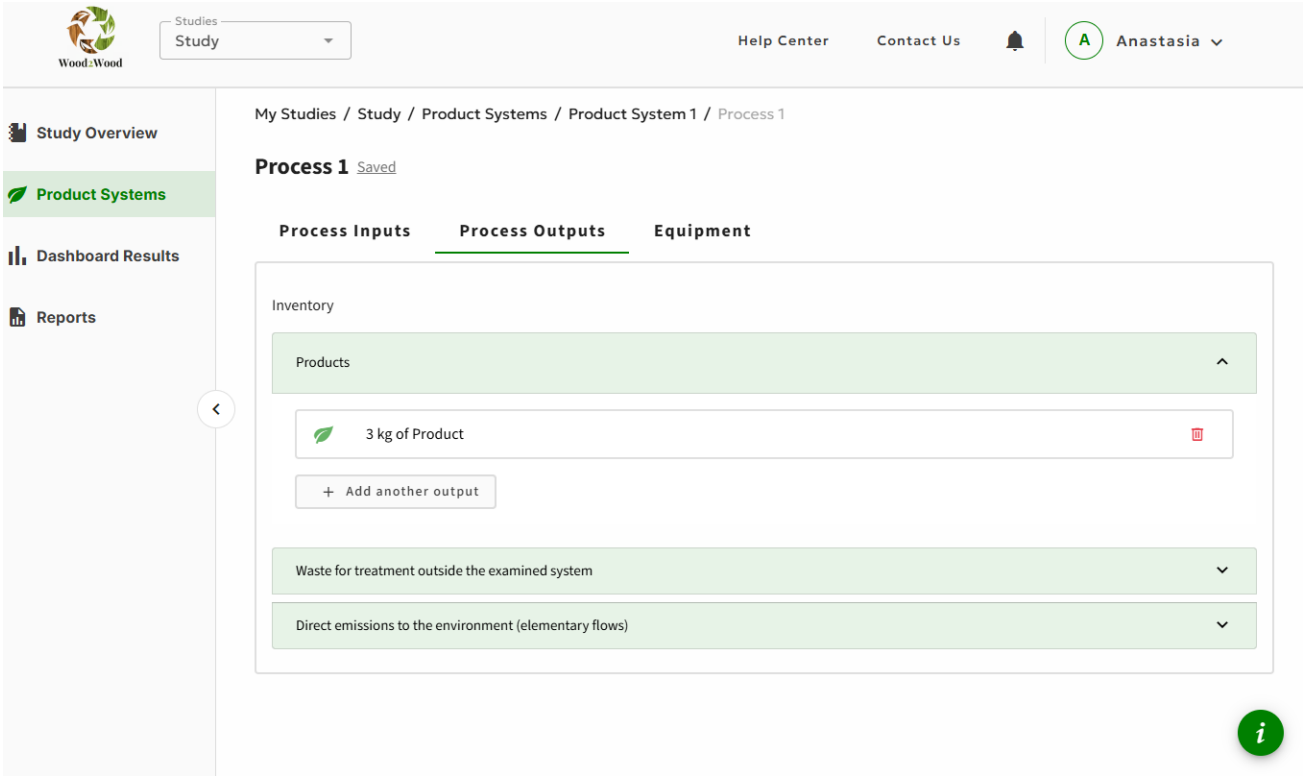

Figure 19: Process outputs page.

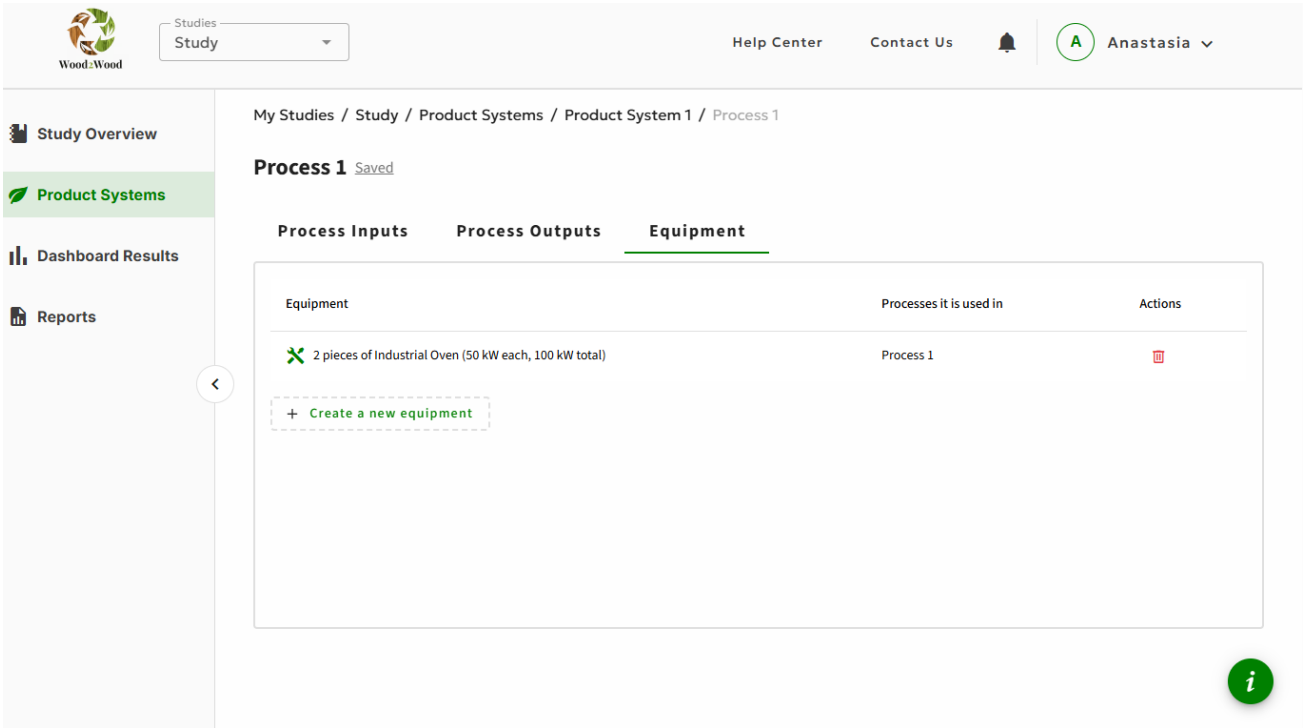

Figure 20: Equipment page.

Table 2: Process data collected through LCI templates.

Process data	Required
Process name	✓
Location (country)	✓
Short description	
Operator (responsible partner)	
Scale	
Category	
Tags	
Time description	
Geography description	
Technology description	
Process schema	
Data quality entry	
Flow schema	
Social schema	

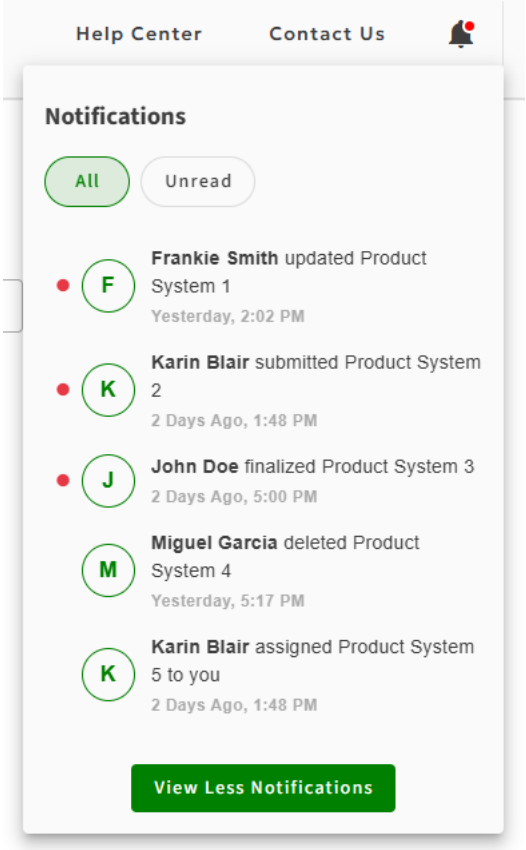

Figure 21: In-app notifications.

Each diagram element can be enriched with data regarding process inputs/outputs (Table 3) and equipment used (Table 4), supporting accurate and transparent sustainability assessments. To support data quality, the tool checks for completeness, consistency, and accuracy of input data, automatically flagging missing or inconsistent entries. The tool guides analysts step-by-step

through the entire study workflow, offering recommended actions such as “Submit Product System” or “Calculate Results” to complete each phase. The data fields included in the LCI templates (Table 2 - Table 4) are selected in alignment with the official OpenLCA schema documentation [1] to ensure consistency and compatibility with established data structures.

Table 3: Process input/output data collected through LCI templates.

Process input/output data	Required
Name	✓
Type	✓
Quantity	✓
Unit (SI)	✓
Production origin	✓
Quantity source	
Details	
Assumptions / comments	

Table 4: Equipment data collected through LCI templates.

Equipment data	Required
Name	✓
Quantity	✓
Power when operating at capacity	✓
Unit of power when operating at capacity	✓
Processes it is used in	✓
Total time it operates for the designated period (to produce 1 FU)	✓
Unit of time it operates for the designated period (to produce 1 FU)	✓
Actual Production Rate	
Unit of actual production rate (Quantity/time)	
Estimation of lifetime for actual production rate	
Unit of lifetime for actual production rate (time)	
Estimation of power for actual production rate	
Unit of power for actual production rate (power unit)	
Capacity of power for actual production rate	
Unit of power for actual production rate (Quantity/time)	
Lifetime when operating at capacity	
Unit of lifetime for actual production rate (time)	
Links which include the equipment specifications	
Name of Model and manufacturer	
Material	
Mass of equipment	
Unit of mass	
Comments	

3.2.6. Results Visualisation and Report Generation

After Environmental-LCA is conducted, the generated results can be imported to the W2W LCSA tool for the generation of result graphs (Figure 22) and an initial LCA report (Figure 23). Upon import, the tool automatically generates a dashboard, to provide an initial visual overview. These charts can include different graphics that are commonly generated by conventional tools, or different results combinations, according to the user specifications and needs, allowing for a fully customisable presentation of the impact analysis which can improve results transparency and comprehensibility. The generated charts can then be directly embedded into structured reports. These reports are editable within the tool and can be exported in PDF or Word format for further analysis, supporting both internal review and external communication with stakeholders.

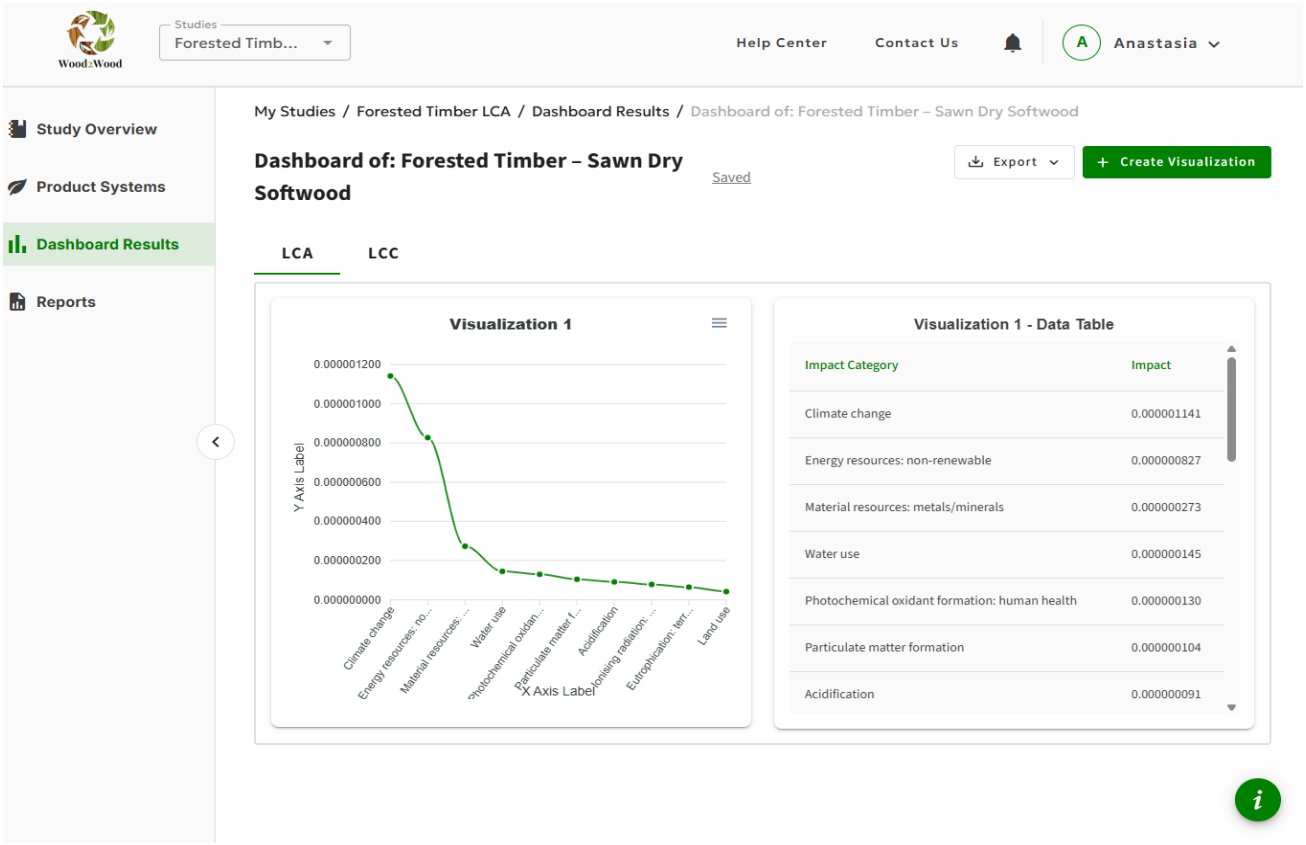

Figure 22: Dashboard page.

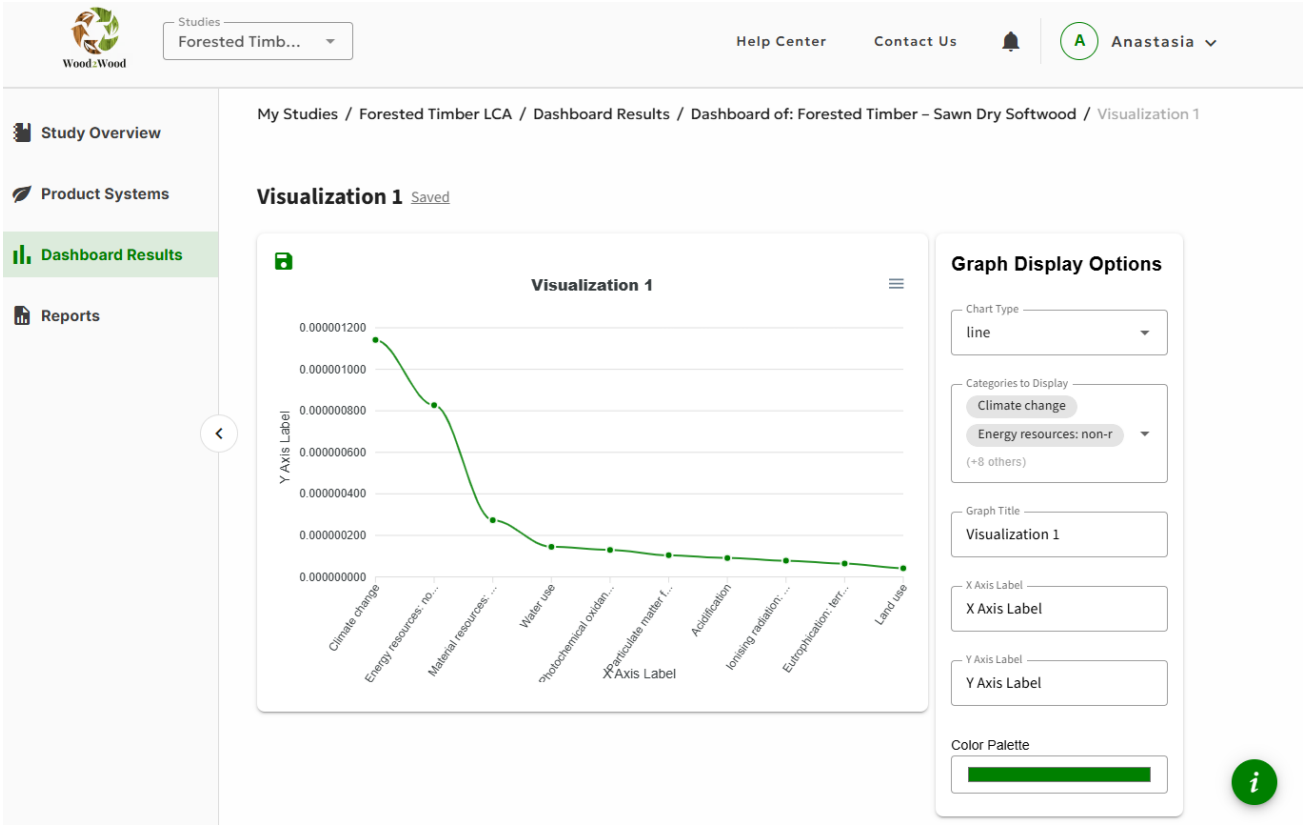

Figure 23: Visualisation editing page.

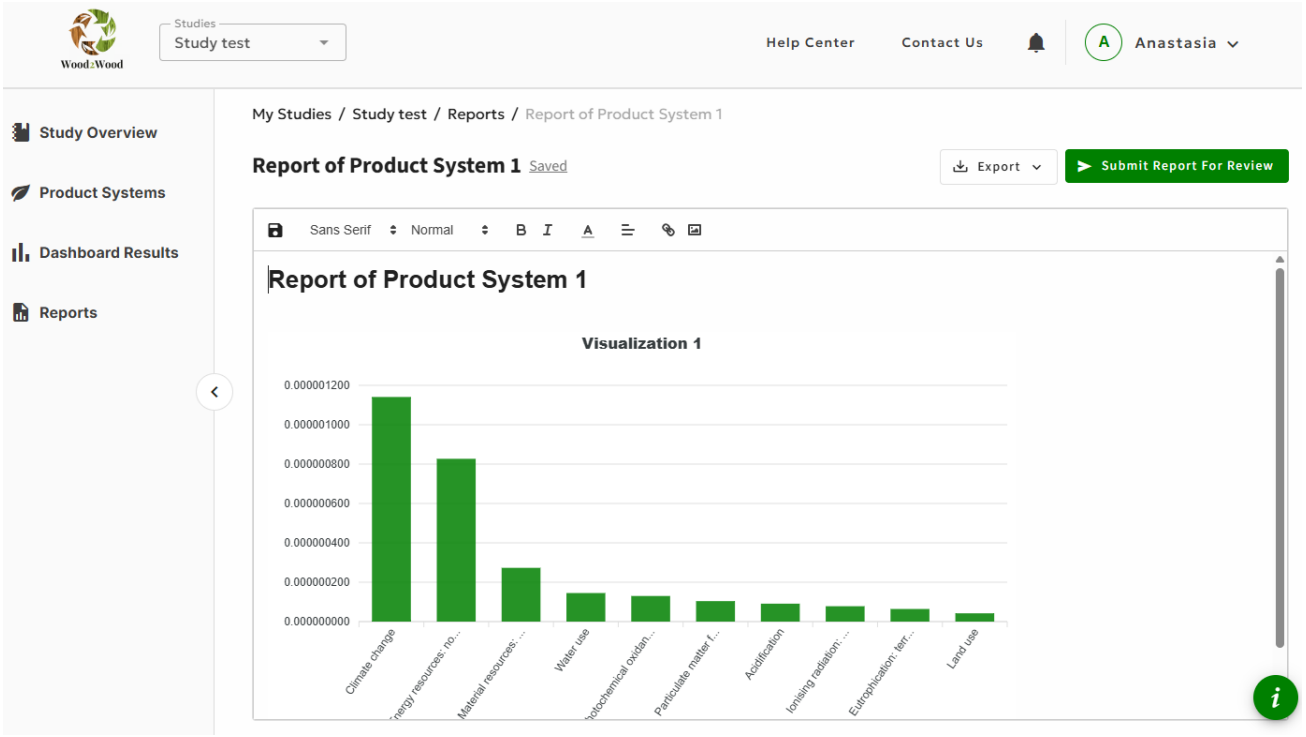

Figure 24: Report page.

4. SYSTEM ARCHITECTURE

The system architecture for this web application is designed to emphasise modularity, scalability, and ease of maintenance. It follows a service-oriented approach where each component is responsible for a distinct domain of functionality, supporting both independent development and frictionless integration. The architectural strategy ensures that the platform can evolve over time without introducing unnecessary complexity, while still meeting the performance, reliability, and security demands of its users.

4.1. TECHNICAL STACK

The web application is built using a containerised architecture optimised for scalability and maintainability. The core technologies include:

i. **Frontend**: Developed using Vue.js (version 3.5), providing a reactive and component-based user interface.
ii. **Backend**: Powered by Laravel (version 11.9), a robust PHP framework that supports RESTful API development and business logic implementation.
iii. **Authentication & authorisation**: Integrated with Keycloak (version 22.0.5), an open-source Identity and Access Management solution. Keycloak handles user authentication, single sign-on (SSO), role-based access control (RBAC), and integration with external identity providers.
iv. **Database**: Uses PostgreSQL (version 14.3) as the primary relational database management system, chosen for its reliability and support for complex queries and data integrity.
v. **Containerisation**: All services are containerised using Docker (version 27.5.0), ensuring consistency across development, staging, and production environments.

This stack provides a secure, scalable, and modular foundation for building and deploying the application efficiently.

4.2. SYSTEM TOPOLOGY

As displayed in Figure 25, the tool includes four core components for data collection:

i. **LCA Library**: A repository of pre-existing information relevant to the assessment, e.g. LCA papers and datasets.
ii. **User Input**: Interactive templates for LCI data collection that allow users to add study-specific data.
iii. **Diagramming**: Visual tools that help structure processes and material flows.
iv. **LCI**: The finalised dataset that consolidates all inputs.

Once LCI data is collected, this inventory can be exported and imported to OpenLCA for environmental impact assessment. In the future internal calculation models will also be supported for this step. The results are re-imported into the platform for:

i. **Visualisation and dashboarding**: Interactive charts or visual summaries to explore impact data.
ii. **Reporting**: Structured output for documentation, stakeholder communication, or decision-making.

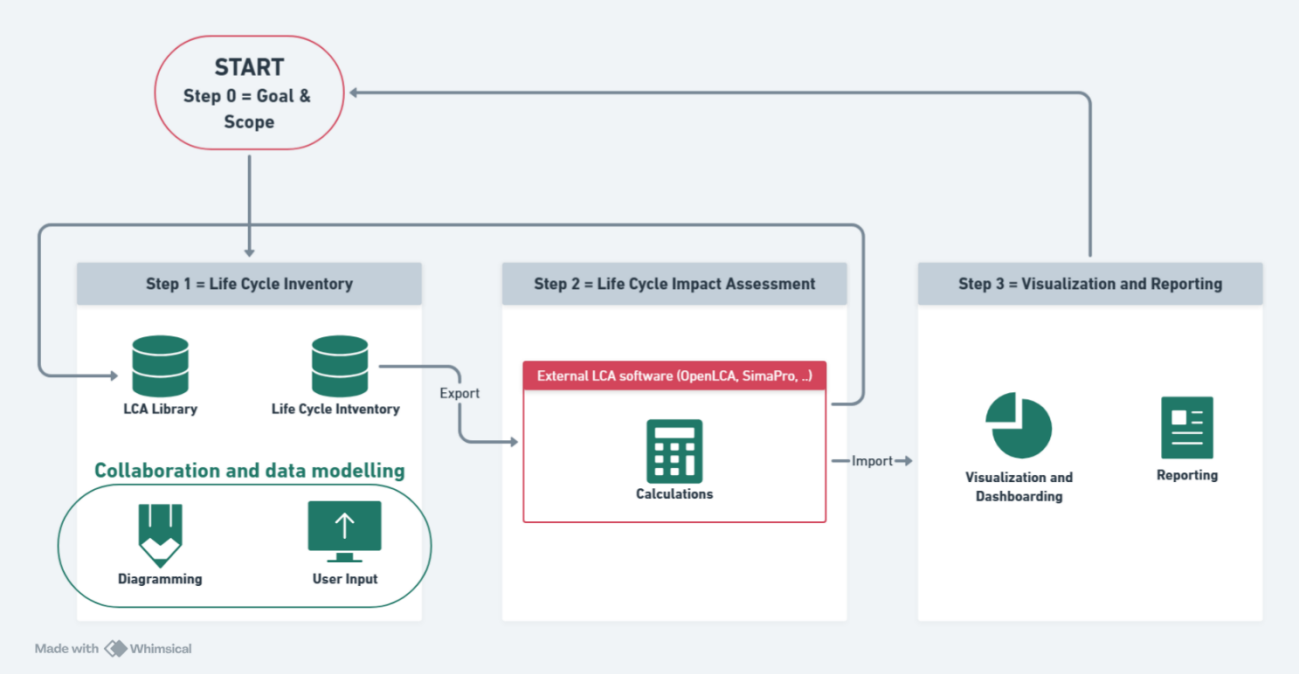

Figure 25: System Topology for version 1, where the red boxes take place outside the tool.

4.3. Data Flow and Integration Points

The data flow within the system is designed to ensure consistency, traceability, and secure handling of user input and analysis of results across different components. Here's how information moves through the application:

i. **Frontend to backend**: Users interact with the Vue.js frontend to input data and initiate actions. These are sent to the backend via secure API calls. Laravel handles validation, processing, and database interactions.
ii. **Database layer**: All core data, including studies, user accounts, permissions, and configuration settings, is stored in a PostgreSQL database. Laravel's ORM ensures consistent and secure access to this data layer.

iii. **Authentication and authorisation**: All user authentication is managed via Keycloak, which provides SSO, session management, and role-based access control. The frontend communicates with Keycloak to handle login flows and token management.

iv. **OpenLCA import/export:** Data from the system is exported in a structured ZIP format compatible with OpenLCA. After processing in OpenLCA, the user imports the resulting Excel files back into the system. This imported data is parsed and used to generate visual dashboards and insights. OpenLCA software was selected for conducting all Life Cycle Impact Assessment (LCIA) calculations due to its open-source nature, which allows transparency and customisation. It adheres to key international LCA standards, such as ISO 14040/44, and supports major databases like Ecoinvent, thus supporting consistent methodology and data compatibility. Moreover, its flexible architecture makes it highly suitable for achieving interoperability and integration with other tools and systems.

v. **Dashboard rendering**: Once processed, study results are transformed into interactive dashboards within the frontend. These visualisations rely on dynamic data queries and are tailored based on the user's role and the study configuration.

vi. **Containerised deployment**: All components run within Docker containers, ensuring isolated, reproducible environments across development and production. This includes separate containers for the Laravel backend, PostgreSQL database, Keycloak server, and supporting services.

This architecture (Figure 26) ensures secure and scalable communication between all components, with clear integration points that support both internal workflows and external tools like OpenLCA.

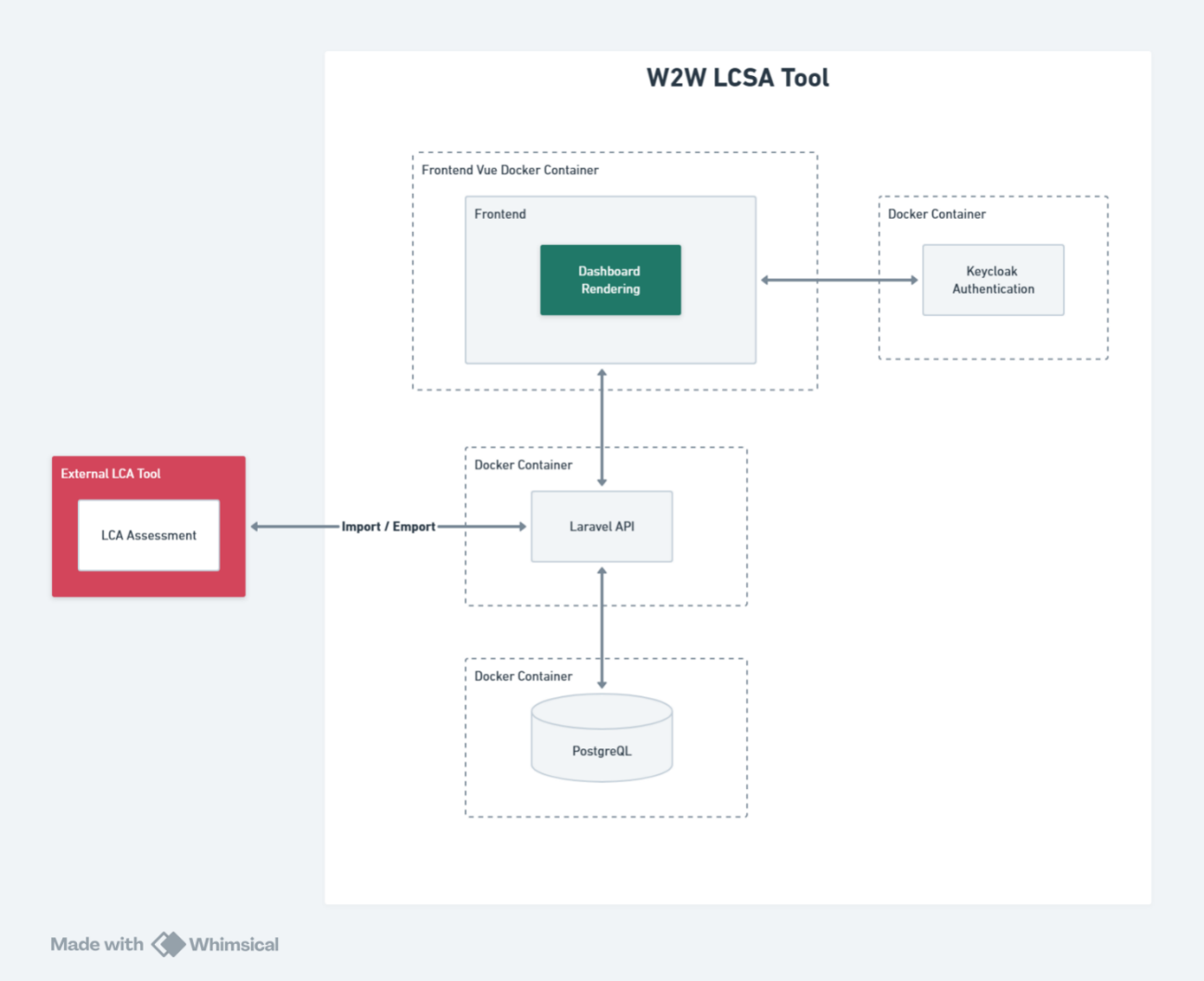

Figure 26: Data flow inside the tool and interaction with external LCA tools.

4.4. Quality Assurance

The quality assurance process for this application is designed to ensure reliability, performance, and security throughout the development lifecycle. A combination of manual testing, automated tools, and industry-standard practices is used to validate that the application meets functional requirements, performs well under load, and adheres to best practices for code quality and security. The following sections detail the strategies and tools employed across various aspects of testing and quality control.

4.4.1. Functional Testing

Functional testing for the application is currently performed primarily through manual, hands-on validation. This approach involves developers and testers interacting with the application's user interface and APIs to verify that key features behave as expected. Manual testing allows for rapid iteration during development and provides immediate feedback on changes, especially useful during early stages or when working with fast-moving feature requirements.

All major user flows — including authentication, form submissions, CRUD operations, and role-based access — are regularly verified in development and staging environments prior to

deployment. Testers follow predefined use-case scenarios, and edge cases are checked on a case-by-case basis, particularly after significant feature updates or refactors.

4.4.2. Load and Stress Testing

Load and stress testing were conducted to validate the application's behaviour under normal and peak usage conditions. These tests aimed to assess system stability, scalability, and error-handling capability under varying user loads. The backend API, developed in Laravel, and the frontend, built with Vue.js, were both subjected to rigorous testing scenarios using Apache JMeter as the primary tool.

The load testing phase simulated a steady stream of 100 concurrent users interacting with key application endpoints over a sustained period of 10 minutes. This scenario was designed to mimic expected real-world usage. The focus was on response time consistency, request throughput, and server resource utilisation. During the test, the system maintained stable performance, with an average response time of approximately 850 milliseconds and a maximum observed latency below 1.5 seconds. CPU and memory usage on the server remained within acceptable thresholds, and no bottlenecks or degradation in user experience were detected.

For stress testing, the system was pushed beyond its anticipated operational limits to evaluate how it handles extreme conditions. A spike test was configured to introduce 500 virtual users within 30 seconds. This sudden influx was intended to test the elasticity and resilience of the application under stress. While the response times increased marginally during peak load, the application continued to process requests without failure. Error rates remained below 2.5%, and the server did not crash or require a restart, indicating robustness and graceful degradation under duress.

All test results met or exceeded the predefined success criteria: a target error rate of less than 3%, and 95% of all requests completing in under 1.5 seconds. These outcomes confirm that the application is well-prepared to handle both sustained load and unexpected traffic surges.

4.4.3. Security Testing

Security validation for the application primarily relies on Laravel’s comprehensive, out-of-the-box security features. Laravel provides a robust foundation that addresses many common web vulnerabilities by default, significantly reducing the risk surface without the need for extensive custom implementation.

Laravel’s Cross-Site Request Forgery (CSRF) protection is enabled by default across all forms and routes using the built-in CSRF middleware. This ensures that any unauthorised or forged request originating from an external source is automatically rejected unless it contains a valid CSRF token.

SQL Injection is mitigated through Laravel’s use of parameter binding in all database interactions, including Eloquent ORM and the Query Builder. This mechanism ensures that input values are never directly concatenated into SQL queries, preventing malicious inputs from altering the intended behaviour of the database commands.

Cross-Site Scripting (XSS) risks are also minimised by default through Blade’s templating engine, which automatically escapes all variables unless explicitly marked as raw. This automatic output encoding prevents user-provided data from injecting executable JavaScript into the page.

Authentication is handled using Laravel's built-in authentication scaffolding, which includes secure password hashing (via bcrypt or Argon2), login throttling to prevent brute force attacks, and session-based user management with encryption. Laravel also offers secure route middleware, allowing granular control over access permissions and route protection.

4.4.4. Code Quality

To maintain a consistent and maintainable codebase across both the backend and frontend, the development team has implemented automated code formatting and linting processes. These ensure that the code adheres to established style guidelines and remains free of basic syntactic and structural issues that can lead to bugs or reduce readability over time.

On the backend, the Laravel application uses Laravel Pint, a zero-configuration PHP code style fixer built on top of PHP-CS-Fixer. Pint is fully compatible with Laravel's default style conventions and is run automatically during development and as part of the CI process. It enforces spacing, alignment, import ordering, indentation, and naming conventions across all PHP files. By consistently applying Pint, the team ensures that the backend codebase remains clean, readable, and aligned with modern Laravel best practices. The use of Pint also helps reduce code review overhead by eliminating debates over formatting and style.

For the frontend, the Vue.js code is analysed using ESLint, configured to follow recommended rules along with Vue-specific linting plugins. ESLint is integrated into the development workflow and CI pipeline, helping catch potential issues such as unused variables, unreachable code, inconsistent formatting, and deprecated JavaScript patterns. ESLint also enforces component structure conventions and ensures that Vue templates, scripts, and styles are organised in a maintainable and standardised way.

4.5. CONFIDENTIALITY

The W2W LCSA tool has been designed with confidentiality at its core, recognising the sensitive nature of life cycle data, including proprietary process information, product systems, and impact results. To ensure secure collaboration, the platform uses the RBAC access control system that allows LCA analysts to manage visibility and permissions at the study, product system, and dataset levels, defining whether a study is private, shared with specific users, such as other LCA analysts or stakeholders, preserving control over who can view or edit critical data.

The tool supports secure and standardised data exchange by enabling both import and export of LCI data using the OpenLCA schema [1]. This ensures high compatibility with external LCA tools such as OpenLCA, while maintaining data structure integrity and semantic consistency. By relying on a well-established schema, the risk of misinterpretation, data corruption, or loss of contextual meaning during transfer is reduced.

5. DEPLOYMENT AND ACCESS

The deployment and access strategy for the application is designed to balance operational control, security, and ease of use for both technical administrators and end-users. By leveraging containerisation and a dedicated hosting environment, the system ensures consistent performance, straightforward maintenance, and a high degree of reliability. The deployment pipeline is optimised for repeatability and scalability, allowing the development team to manage updates and environment changes with minimal disruption.

5.1. HOSTING ENVIRONMENT

The application is deployed on a dedicated server, ensuring full control over the hosting environment and system resources. The entire stack is containerised using Docker, allowing consistent and isolated environments for the frontend, backend, database, and authentication services.

The deployment setup includes:

i. **Docker Compose** to orchestrate multi-container services (e.g., Laravel backend, PostgreSQL, Keycloak, Vue frontend).
ii. **Environment configuration files (.env)** for managing deployment variables.
iii. **Routine maintenance and deployment** are handled directly on the server via SSH and Docker CLI, allowing for straightforward updates and scalability.

This setup offers flexibility, isolation between components, and simplifies environment replication for staging or testing purposes.

5.2. ACCESS INSTRUCTIONS

Below are the access methods and configurations:

i. **User access**: The application is accessible via a secure web URL. All users are required to authenticate through Keycloak, which handles login, session management, and user role enforcement.
ii. **Developer/Administrator access**: Administrative access is granted via SSH into the dedicated server. From there, developers and system admins can manage Docker containers, view logs, and apply updates.
iii. **Environment configuration**: Access credentials, domain settings, and other environment-specific parameters are managed via .env files within the Docker setup.

This setup ensures secure, reliable access for both end-users and technical administrators while maintaining a streamlined deployment workflow.

5.3. USER ROLES AND PERMISSIONS

The W2W LCSA tool includes the following user roles:

i. **Analysts**: LCA experts, the primary user that conducts LCAs, manages data, and generates dashboards and reports for internal use or stakeholders.
    a. Responsibilities:

i. Create, edit, and share studies
ii. Analyse and validate data with pilots (use case partners)
iii. Generate dashboards and reports

b. Access Permissions:
i. Full access to own and shared studies
ii. View/upload items in the shared LCA Library
iii. Manage their account (not role)

ii. **Pilots**: The stakeholder who provides data (i.e. the use case partners), collaborates on study development, and reviews the results of LCA studies.

a. Responsibilities:
i. Fill out LCI data
ii. Help develop process diagrams
iii. View results and request further analysis
iv. Approve/download reports

b. Access Permissions:
i. Edit templates/diagrams with analyst permission
ii. View shared studies, results, and reports
iii. Review reports when permitted
iv. View related notifications
v. Manage their account (not role)

Unregistered users are prompted to sign in or create an account.

6. NEXT STEPS

Version 2 of the W2W LCSA tool will not only revisit and complete features from Version 1 but also introduce new features that enhance analytical power, collaboration, and decision support, improving user experience, and integrating advanced capabilities that align with the tool's long-term goals. Furthermore, the tool will support additional user roles to better accommodate diverse user needs and better management.

6.1. PLANNED FEATURES FOR VERSION 2

Planned features of the W2W LCSA tool are the following:

i. **Import, export (continued from v1)**: Complete mapping to OpenLCA schema.
ii. **In-app notifications (continue from v1)**: Alerts for data submissions, study finalisation, and task deadlines.
iii. **Automatic dashboard creation (continue from v1)**: Complete auto-generation of dashboards from results data.
iv. **Version control**: Tracks changes, allows reversion, and logs user edits in LCA templates and data.
v. **LCC and S-LCA calculations**: Develop integrated capabilities for both LCC and S-LCA. This will involve first establishing the necessary methodological foundations, such as defining modelling approaches, before implementation. The development will be supported by real-world data from pilot projects to ensure that both LCC and S-LCA modules are contextually relevant and accurate.
vi. **ML integration**: Investigate the use of ML to support the workflow of the tool.
vii. **Simulation scenarios**: Explore the implementation of scenario simulation features to simulate changes and view impacts.
viii. **Email notifications**: Sent for key actions like project finalisation or new data requests.
ix. **Static pages**: Populate content for terms, privacy policy, FAQ, about, etc.
x. **Admin-related features**: A dedicated administrative user role with full oversight of tool operations.
xi. **Integration points with other tools**: Investigate potential interactions between the LCSA tool and other W2W tools; elucidate integration with the Integrated Circular Wood Upcycling Platform.

6.2. PLANNED USER ROLES FOR VERSION 2

The tool will have an additional administrative user role, serving as the primary manager who oversees tool configuration, user management, and system integrity, and having the following responsibilities and access permissions:

i. **Responsibilities**:
    a. Manage user accounts and roles.
    b. Maintain system settings and datasets.
    c. Ensure data confidentiality.
ii. **Access permissions**:
    a. Full access to all studies and user accounts.
    b. Can edit, share, delete, or restore any study, dashboard, or report.

c. Full control over the LCA Library.
d. Can view all in-app notifications.

6.3. TIMELINE FOR VERSION 2

Action points and timeline for version 2 (M19 to M36) are included in the Table 5.

Table 5: Timeline of the second version of the W2W LCSA tool.

No.	Action	Duration	Months
1	Analyse and determine all v2 functionalities	3 months	M19 - M21
2	Document detailed functional and technical specifications for v2	2 months	M22 – M23
3	Create high-fidelity mock-ups for v2	1 month	M24
4	Internal review and validation of mock-ups and scope for v2 with project partners and development teams	1 month	M25
5	Frontend and backend development of v2	6 months	M25 – M30
6	Functional, performance & integration testing	1 month	M31
7	LCI data collection from use case partners	Iterative rounds	until M33
8	Conduct impact assessment calculations (LCA, LCC & S-LCA)	Iterative rounds	until M35
9	User testing	Iterative rounds	until M35
10	Corrections from user testing and final QA testing	2 months	M35 – M36
11	Preparation and submission of D14.4	1 month	M36

7. CONCLUSION

The development of the first version of the W2W LCSA tool has established the basic structure, methodologies and data flows needed to support the assessment of sustainability impacts along wood reuse pathways. This initial version enables pilot partners to collaborate with analysts on LCA studies, input process-specific data, and explore outcomes through interactive dashboards and reporting features. Further development will continue in the context of task T14.4 and result in the final version to be delivered in WP14, focusing on extending the tool's capabilities. Continuous stakeholder engagement will continue to play a central role in shaping key features and interface improvements, ensuring the platform responds to the needs of the W2W project.

8. ANNEXES

8.1. ANNEX A: USER INTERFACE MOCK-UPS

As part of the design and planning phase for Version 1, initial user interface mock-ups (Figure 27) were created using Figma to visualise and test the intended workflows of the W2W LCSA Tool. These mock-ups were developed following design research and requirements gathering with project partners. These designs served as the basis for early feedback and iterative refinement and were presented to partners for review and validation.

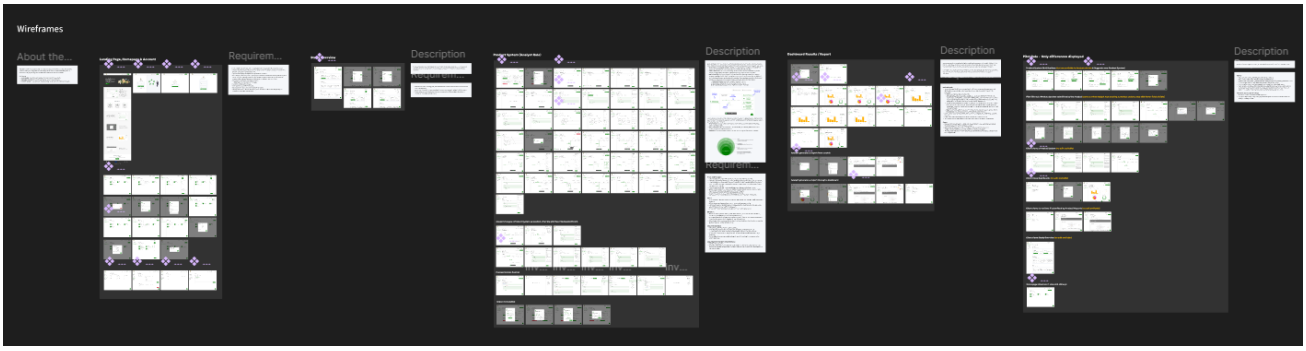

Figure 27: Figma-based interface mock-ups showing the proposed user flow and layout for Version 1.

8.2. ANNEX B: DATA

The methodology used within the tool for conducting a LCA study and building templates for LCI data collection is grounded in internationally recognised ISO standards 14040/14044:2006 [2 - 3] and the ILCD Handbook[1] . The tool is designed to streamline and improve on all ISO indicated stages of LCA, which include: 1) Goal & Scope Definition, 2) LCI, 3) LCIA and 4) Interpretation.

It facilitates comprehensive data collection for the LCI phase, covering material and energy inputs, emissions, and waste flows across all stages of the life cycle. Goal and scope definition stage includes the functional unit (FU) and system boundaries definition. In the tool, a field for demonstrators to suggest their FU is provided, under monitoring of the LCA practitioner/expert. W2W LCSA tool is also designed to provide clear guidance for the correct definition of the system boundaries of the analysis, in the form of sequential steps. Through user-friendly GUI, the tool allows demonstrators to design their own system boundaries in a simplified flow-chart, suitable for users with limited or no experience with LCA analysis.

The tool guides the process, providing different modules for different processes and their interconnections, including transportation activities occurring internally in the designed system. In addition, system boundaries design process is also accessible to the LCA analyst, allowing for overall monitoring of the process, mitigating errors on the spot, significantly enhancing time efficiency and analysis accuracy.

[1] https://eplca.jrc.ec.europa.eu/ilcd.html

Specifically, the tool allows stakeholders to list their processes, define internal connections and generate the system boundaries graphic, as shown in Figure 28 - Figure 31 (the figures below present the conceptual design and not the developed Graphical User Interface itself).

List of processes	Short description	Operator (responsible partner)	Location (Country)	Scale (Lab, pilot, industrial)
Process 1	Process 1 description		GR	
Process 2	Process 2 description		GR	
Process 3	Process 3 description		GR	
Process 4	Process 4 description		GR	
Process 5	Process 5 description		GR	

Figure 28: Process list.

Process connections (Flow Provider vertically, Flow Receiver horizontally)	Process 1	Process 2	Process 3	Process 4	Process 5
Process 1	-	X (Int.fl 1-2 generated)			
Process 2		-		X (int.fl2-4 generated)	
Process 3		X (int.fl 3-2 generated)	-		
Process 4				-	X (int.fl 4-5 generated)
Process 5					-

Figure 29: Process interconnections definition.

List of internal transport	Are there energy consuming internal transport activities? (Road, Other, None)
Internal transport 1-2	Road
Internal transport 2-4	Road
Internal transport 3-2	
Internal transport 4-5	

Figure 30: Definition of internal transportation activities in the system boundaries.

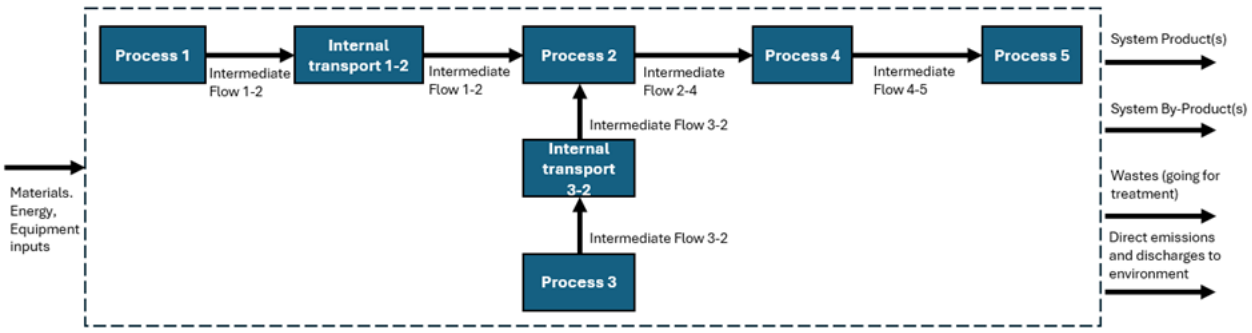

Figure 31: Generated system boundaries.

Figure 32 & Figure 33 present the concept of LCI data collection templates provided to stakeholders. Compared to conventional LCI data collection activities and stakeholder/LCA analyst collaboration tools, these templates provide a breakdown of all input/output categories, as well as required information for the practitioner that needs to be collected for a holistic and accurate assessment.

Data collection												
	Demonstrator fields						LCA practitioner fields					
PROCESS X	Quantity	Unit (SI)	Production origin (if unknown then purchase origin)	Quantity source (measurements, estimations, calculations, literature etc.)	Details (links to literature, equations etc.)	Assumptions / Comments	Adjusted quantity	Unit	CATEGORY	Type	Used dataset	LCA practitioner Comments
Process Inputs												
Material inputs (primary or secondary raw material and ancillary material, other physical inputs)												
Water use (all water used in the process)												
Energy use. These can be direct measurements from meters or calculated by the operating time and power of used equipment												
Electricity												
Heating fuels												
Other												
Inputs from nature/ elementary inputs (These are inputs coming to the process DIRECTLY from nature, without ANY processing prior to their introduction.												
Process Outputs												
Products (coming out of the system, otherwise considered intermediate inputs												
Process product(s). If one or more is the system product, please specify. If not, one or more should serve as intermediate inputs for another process in the boundaries (as defined in the "System boundaries" tab). For these, please specify the process(es)												
Valuable by-product(s) (valuable outputs that are not the system's intended products, but can be sold/used to other systems)												
Substituted products (products that can be substituted by the examined system products and by-products) In these cells, specify the system product and the product that it can substitute												
Waste for treatment outside the examined system												
Liquid wastes (liquid wastes that undergo treatment outside the system)												
Solid wastes (solid wastes that undergo treatment outside the system)												
Direct emissions to the environment (elementary flows)												
Direct emission to air (emissions to air that are directly released in the atmosphere without treatment)												
Direct discharges to water (discharges to water that are directly released in the environment without undergoing treatment. Specify next to the flow name if it is discharged to sea or fresh water bodies)												
Direct discharges to soil (discharges that are directly released to soil/ground without undergoing any treatment)												

Figure 32: LCI data collection template/fields.

Road Transport, include both upstream transports (for flows entering the system), internal transports (for flows moving from one process to another, both inside the system boundaries) and downstream transports (flows exiting the system). It also include transport of wastes							
Internal transports							
Name of flow transported	Distance (km)	Type of vehicle (i.e Lorry Euro 1-6, Lorry Euro unregulated, Other)	Fuel used	Capacity (tonnes)	Actual load (tonnes)	Empty return (Yes/No)	Refrigerant (only for vehicles with refrigeraiton
Intermediate flow 1-2							
Intermediate flow 3-2							
Upstream transports							
Name of flow transported	Distance (km)	Type of vehicle (i.e Lorry Euro 1-6, Lorry Euro unregulated, Other)	Fuel used	Capacity (tonnes)	Actual load (tonnes)	Empty return (Yes/No)	Refrigerant (only for vehicles with refrigeraiton
Downstream transports							
Name of flow transported	Distance (km)	Type of vehicle (i.e Lorry Euro 1-6, Lorry Euro unregulated, Other)	Fuel used	Capacity (tonnes)	Actual load (tonnes)	Empty return (Yes/No)	Refrigerant (only for vehicles with refrigeraiton

Figure 33: LCI data collection template/fields – transportation specific

Fields are divided between “Demonstrator fields” and “LCA practitioner fields”. In the first subdivision, stakeholders (demonstrators) provide all the information required for the assessment. In the second subdivision, LCA analysts (LCA practitioners) can make any adjustments and/or additions necessary to prepare the LCI data for assessment (such as quantity or unit corrections). These fields are editable only by the LCA Analyst. The final product of the LCI data collection phase of the tool is a downloadable file, compatible with LCA software (such as OpenLCA), which can be immediately imported into the tool, significantly reducing the time required for LCA analysts to model the examined systems.

9. REFERENCES

[1] GreenDelta, “OpenLCA schema,” *Github.io*, Oct. 31, 2014. https://greendelta.github.io/olca-schema/ (accessed Jun. 02, 2025).

[2] International Organization for Standardization, *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework*. 2006. Accessed: Jun. 02, 2025. [Online]. Available: https://www.iso.org/standard/37456.html

[3] International Organization for Standardization, *ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines*. 2006. Accessed: Jun. 02, 2025. [Online]. Available: https://www.iso.org/standard/38498.html

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