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Funded by the European Union. This project has received funding from the European Union's Horizon Europe, grant number 101057765. This includes funds from the UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee, grant number 10038028.

GREEN-LOOP

Sustainable manufacture systems towards novel bio-based materials

WP2 – Sustainability and Circularity by design

D2.9 – GREEN-LOOP online platform

Version 1.0

Document information

Contractual Due date: 31.08.2024

Delivery Date: 30.08.2024

Author(s): IDENER

Lead Beneficiary of Deliverable: IDENER

Dissemination level: Public

Nature of the Deliverable: OTHER, accompanied by the present report.

Internal Reviewers: IDENER

GREEN LOOP Key Facts

Project title	Sustainable manufacture systems towards novel bio-based materials
Starting date	09/01/2022
Duration in months	36
Call (part) identifier	TWIN GREEN AND DIGITAL TRANSITION 2021 (HORIZON-CL4-2021-TWIN-TRANSITION-01)
Topic	HORIZON-CL4-2021-TWIN-TRANSITION-01-05 Manufacturing technologies for bio-based materials (Made in Europe Partnership) (RIA)
Consortium	17 organizations: 15 from EU Member States + 2 from UK

GREEN LOOP Consortium Partners

	Partner	Acronym	Country
1	IDENER RESEARCH & DEVELOPMENT	IDE	ES
2	NATIONAL INSTITUTE OF CHEMISTRY	NIC	SI
3	SLOVENIAN NATIONAL BUILDING AND CIVIL E. I.	ZAG	SI
4	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V	FHF	DE
5	LABRENTA SRL	LBRT	IT
6	MIXCYCLING SRL	MYX	IT
7	NERO SU BIANCO	NSB	IT
8	GERACE MARIA CRISTINA - TERRE DI ZOE'	TDZ	IT
9	IRIS TECHNOLOGY SOLUTIONS, SOCIEDAD LIMITADA	IRIS	ES
10	GLOWNY INSTYTUT GORNICTWA	GIG	PL
11	AACHEN UNIVERISTY: PROCESS CONTROL ENGINEERING / AACHEN UNIVERISTY: INSTITUTE OF SOCIOLOGY	AAU	DE
12	AUSTRIAN STANDARDS INTERNATIONAL	ASI	AT
13	INSTITUTO DE SOLDADURA E QUALIDADE	ISQ	PT
14	AXIA INNOVATION UG	AXIA	DE
15	ASOCIACIÓN DE INVESTIGACIÓN METALÚRGICA DEL NOROESTE	AIMEN	ES
16	NATIONAL COMPOSITE CENTER	NCC	UK
17	UNIVERSITY OF BRISTOL	UBRIS	UK

Disclaimer: GREEN LOOP is a project funded by the European Commission under the Horizon Europe - HORIZON-CL4-2021-TWIN-TRANSITION-01-05- Manufacturing technologies for bio-based materials (Made in Europe Partnership) (RIA) under Grand Agreement Number 101057765.

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Executive Summary

The "D2.9 – GREEN-LOOP Online Platform" deliverable explains the development of the GREEN-LOOP platform, a digital tool designed to enhance sustainability and circularity in the production of novel bio-based materials. This deliverable is a result of Task 2.5 and an important part of the GREEN-LOOP project. The GREEN-LOOP platform serves as a multidisciplinary hub, facilitating the optimization of value chains from raw material sourcing to end-of-life processes such as recycling, reuse and refurbishment. It supports the creation of new bio-based products and provides an in-depth analysis of environmental and social impacts. Through real-time data integration from manufacturing facilities, continuous environmental evaluations and socio-economic analyses, the platform helps stakeholders identify and capitalize on sustainable business opportunities.

Key features of the platform include modules for real-time data collection, environmental performance assessments, business optimization using artificial intelligence and social engagement. The platform architecture is built on a microservices framework, ensuring flexibility. Technologies such as Docker containerization, Python-based microservices and Apache Kafka for real-time data streaming have been employed to develop a dynamic and efficient system.

The current report accompanies the platform's code release, detailing the technical design and implementation decisions that have been followed. It highlights the modular approach adopted, with each module representing distinct functionalities that contribute to the overall goal of sustainability and circularity. The platform is positioned as a living platform, to be continuously updated as the project progresses and new features are integrated.

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Abbreviations

API	Application Programming Interface
GA	Grant Agreement
GUI	Graphic User Interface
URL	Uniform Resource Locator

1. Introduction

The GREEN-LOOP online platform represents a significant step forward in the development of digital tools aimed at enhancing sustainability and circularity in bio-based manufacturing systems. Designed to integrate and optimise various aspects of the value chain, the platform provides a comprehensive suite of functionalities, including real-time data analysis, environmental performance assessment and value chain optimisation. This deliverable D2.9 focuses on detailing the status of the platform, including its architecture, development progress and initial deployment.

The platform is structured around a microservices-based architecture that facilitates flexibility, scalability and modular integration. Key components include data acquisition from manufacturing processes, continuous environmental monitoring, a European map displaying companies and value chains, and customisable and socio-economic analysis modules that support circular business strategies.

This deliverable is organised into 2 big sections. The architecture section discusses the technical design, with subsequent sections that focus on generic and specific modules of the platform, (such as business, social and other optimisation tools), the map, company and value chains displays, and the technologies implemented. The development status section outlines the current progress of each module and components detailed in the previous section.

2. GREEN-LOOP Platform Architecture

The GREEN-LOOP platform is key to the project’s strategy to achieve innovative circular value chains, providing the evaluation framework needed to process the real time information coming from the shopfloor and other sources.

2.1. Initial Architecture

According to the Grant Agreement: “GREEN LOOP value chains will be evaluated and optimised within a multidisciplinary platform that facilitates the analysis of business opportunities from raw materials sourcing to next-use (recycle, reuse, refurbish), enhances activities to create new bio-based products, and assesses environmental and social issues. These results provide information of the social engagement that can be reached, show the business optimisation for each bio-based product, and the circularity aspects such as level of recyclability, refurbish or reuse of the products. The platform will also be part of the training activities; it will contain detailed tutorials, webinars, and examples to boost training activities. Finally, this platform will also serve as a facilitator to ensure sound and effective data sharing for open repositories.”

To this end, the GA presented the architecture described in Figure 1: GREEN-LOOP Platform conceptual architecture, outlining the relations between the value chains and the data acquisition performed over them, and the different functionalities to be integrated into the platform, organized in thematic blocks.

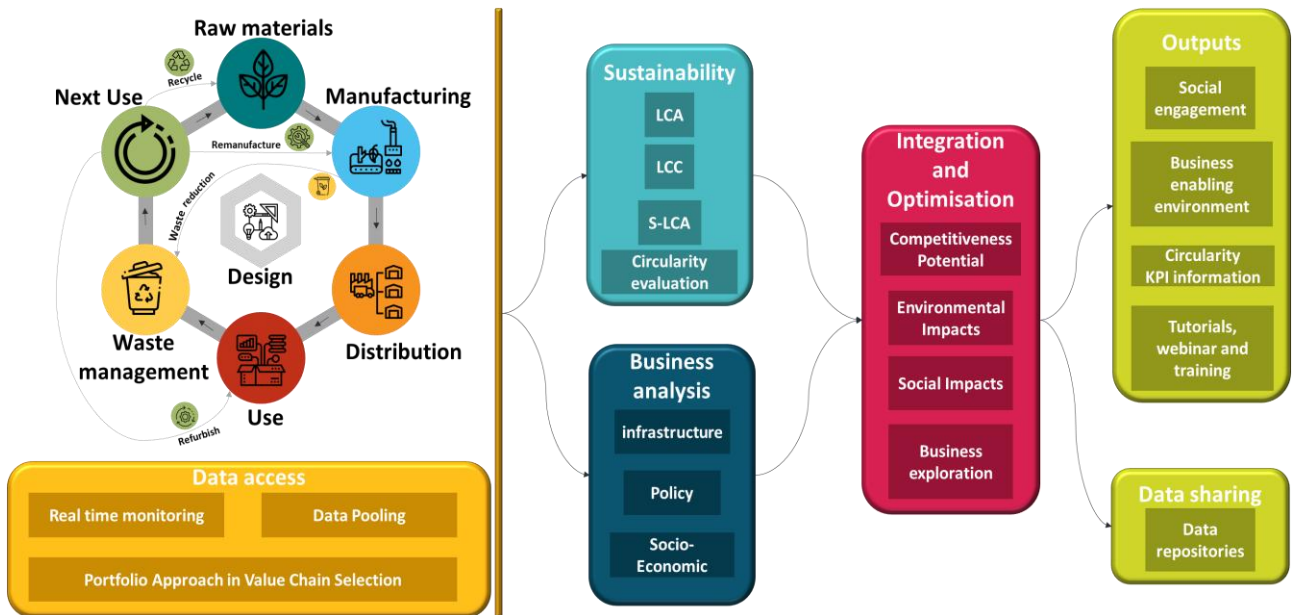


Figure 1: GREEN-LOOP Platform conceptual architecture

In light of the above, IDE will integrate five modules from previous tasks to build the core of the GREEN-LOOP Platform, supported by the partners leading the related tasks as follows:

- Data access (T1.4 and T2.1, IRIS, RWTH AACHEN), data in real-time regarding the status of the manufacturing lines and circularity.
- Sustainability (T2.3, IDE, AIMEN), to perform a constant environmental evaluation. It includes life cycle (LCA, LCC and S-LCA) and Circularity analysis.

- Business analysis (T7.1, AXIA), including sustainable, circular business, policies and socioeconomic models.
- Optimisation (T2.5 and T2.6, IDE), collect results from previous modules to perform the optimisation of the value chain (competitiveness, environmental, social impacts, and business) using optimisation techniques and artificial intelligence trained models.
- Outputs and interface (IDE), user interaction will include the social engagement evaluation and training webinars (T8.4) (ISQ and RWTH AACHEN).

2.2. Updated Architecture

The platform is user-centred to allow information to be easily managed and studied. It defines three distinct user roles, each with specific permissions and access levels to ensure that the right people have the right access to the right information:

1. **Admin:** This role has complete access and control over the platform, ensuring its proper functioning and consistency. Admins can manage all aspects of the platform, including user management, data integrity and system settings. They play a crucial role in maintaining the platform’s security and performance.
2. **Owner:** The Owner can create, edit and delete their companies and value chains. They can also view private data from their own companies and public data from others. Owners have control over their own data and can collaborate with other users by granting permissions.
3. **Stakeholder:** This role is limited to viewing public data from other companies. Stakeholders can access publicly available information, which helps them make informed decisions and engage with other users based on shared interests and goals.

The platform’s permissions matrix ensures that each user role is clearly defined, and users only have access to the features and data necessary for their roles. This approach enhances security, data integrity and user experience.

To better understand the main structure of the platform, this base model is proposed:

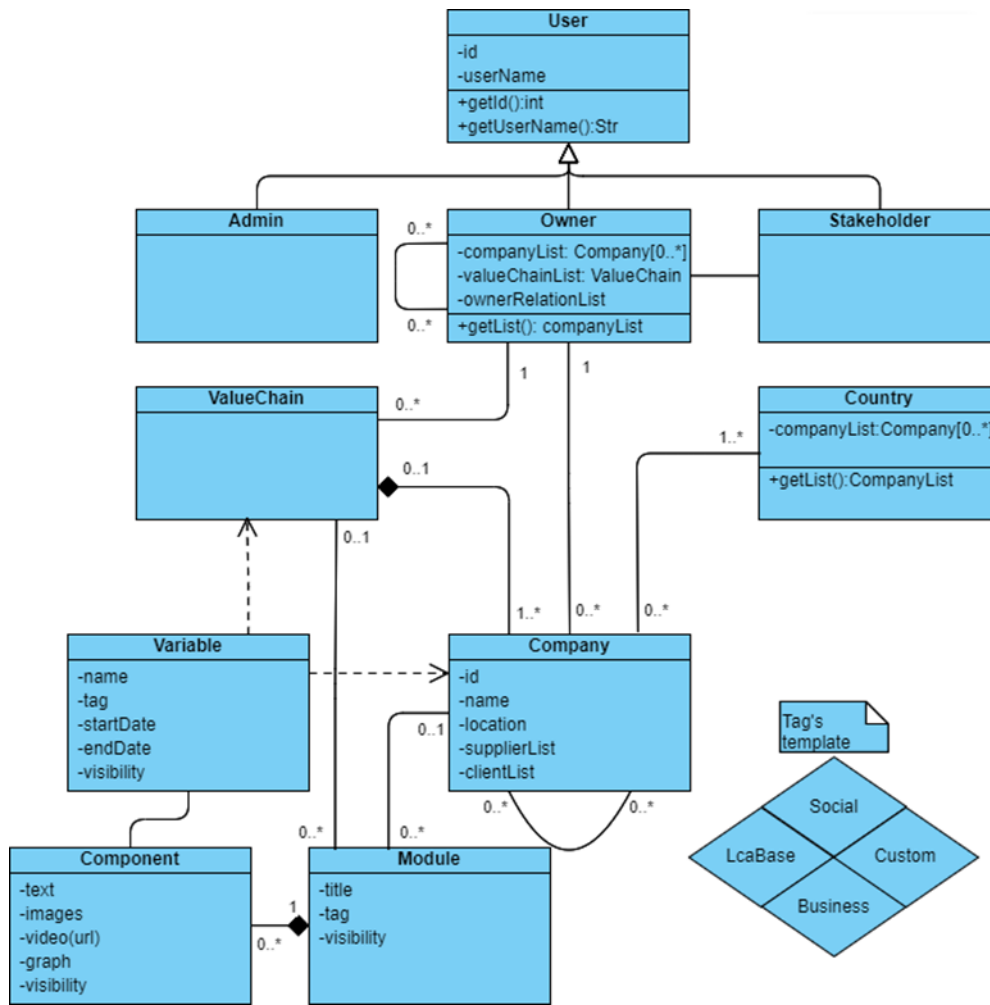


Figure 2: Base Model

For more specific information:

- **Country** class is the most general aggregation of information of the schema. It is the top of the data structure of the platform and the API will use it to display the map for the user.
- **Company** is the core class of the business logic of the platform. Company has a relation with other objects of the same class, creating a chain of suppliers and clients. Also, the objects of these classes can be aggregated in ValueChain class to show and share information. Company has a relation with other objects of the same class, creating a chain of suppliers and clients.
- **Module** is an adaptative container for all users' desires. It will store different types and shapes of data and make it accessible and easily callable for the rest of the platform, controlling user permits and security.
- **Component** is the smallest information aggregator container that organises the data within a module. It groups simpler data to give context or helps with subjects like visualisation.
- **Variable** is a common structure to make it easier to organise variables in components, modules, companies and value chains.

- **LcaBase, Social, Business and Custom** are templates for the Module class. Each template has the basic structure of each module class. In the case of LcaBase that has all common attributes and functions for the LCA and can be implemented in any of the three chains studied in Green Loop (BioPlastic, BioRubber and WoodComposite) or a new one, which will add additional logic and information. Social and Business templates would do the same with respective types of modules, and Custom will lead the user to create the module he wants.
- **Owner** is the key class in the platform information flow. Owner possesses companies and value chains (both or none). Being the owner of something means that this something is the property of the owner, so he has all permits over it. Owner relates with companies of his property, value chains of his property and other Owners. This last relation is the one that will bring permission to edit parts in an external company or value chain. This class will decide which data should be seen or edited, returning/acquiring or not information based on permits.
- **ValueChain**. is a composition of several companies where Owners post and edit content based on permissions given by the Owner of the Value chain. This allows partners to work in separate parts while creating an ensemble value chain.

Owner is the main role in the platform and is the only one who can grant or deny permission, and only to another Owner. An Owner always has full permits over his possessions, like his own company or his own value chain, but this Owner 1 can let Owner 2 edit his value chain, his company, or just a specific module. The value chain, Company, and each created module should give the user the option to create collaboration groups to work.

2.3. Authentication and Registering

Admin has a special page to access. Owner and Stakeholder will access by creating an account and log in by simple access. After login, the Owner and Stakeholder will have a basic form to create their user profile.

Table 1: Register Form

Name	Type	Mandatory(M) / Optional(O)	UI Element
Owner Name	String	M	Textbox
Contact Email	String	M	Textbox
Other contact method	String	O	Textbox
User Icon	Image	O	Selection or Upload
Profile description	String	O	Textbox

The User Icon and Profile description are to make a simple presentation. When creating/editing/looking at a user description or a company contact, this information is shown as a phone like the [Figure 3: Profile example](#).

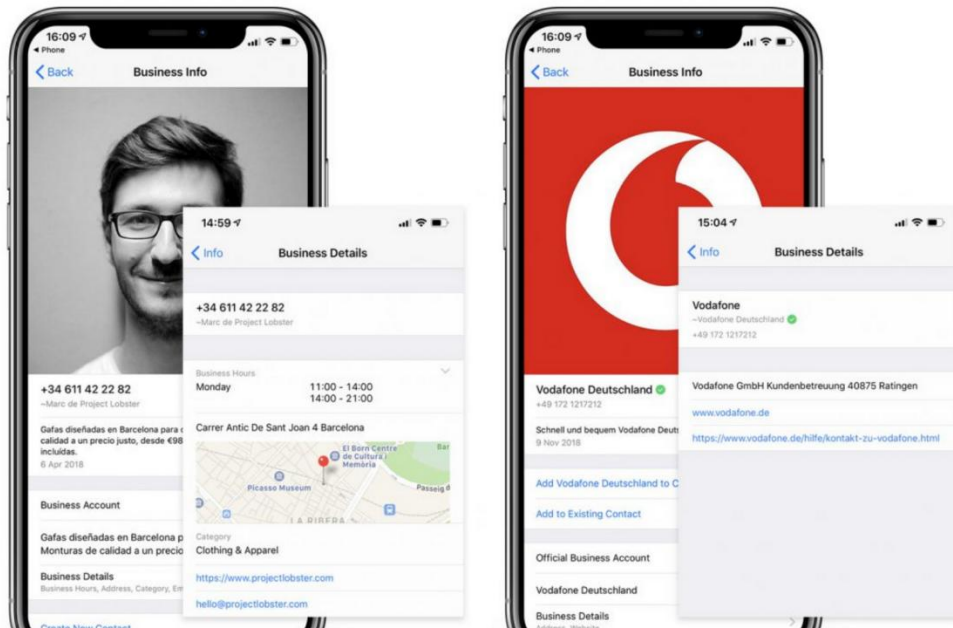


Figure 3: Profile example

In the case of the Owner user type, at this moment, the Owner exists but doesn't own anything.

2.4. Possibilities

The Owner has 4 main options:

- Create a company.
- Create a value chain.
- Look on the map (to search and contact other companies, for example) (stakeholders can also access the map).
- Access the “My administration” page, where a list of his companies and value chains is shown, and another list with the companies and value chains that he has permission to is also shown. Selecting one of them will open the editor page of that company/value chain. On this Editor page, **the Owner can create modules and edit information about other Owners' possessions (and own possessions)** if permission is given. **The editor of a company/value chain can also be accessed via the map.**

2.4.1. Company Creation Form

If the user decides to create a business, the following form structure will appear:

Table 2: Company Creation Form

Name	Mandatory(M) / Optional(O)	UI Element
Company name	M	Textbox
Market of company operation (product)	M	Click in display
Market of company operation (place)	M	Click in display
Company description	O	Textbox
Address	O	Textbox
Link name (Website, Twitter, etc)	O	Textbox
Mail	O	Textbox
Phone number	O	Textbox
Logo	O	Submit file
Value Chain Key	O	Textbox

Company name: The name will be displayed on the map and in the company representation.

Market of company operation (product): The program will display the 3 main products studied in Green Loop and a fourth for customisation.

Market of company operation (place): The country where the company operates (for example: Spain or France) appears on a simple map like this:



Figure 4: European Map

Company description: A text describing the principal aspects of the company.

Address: There are four text boxes, including the number, street, city, and postcode. They are optional, but if the user fills one, he should fill all.

Link name (Website, Twitter, etc.): The text formed by the URL that sends the user to the website. Multiple URLs can be included for social media.

Mail and Phone number will constitute the company contact and it is represented as the phone picture above (it is not mandatory to coincide with the company Owner).

Logo: An image of the company logo to be displayed in company representation.

Value Chain Key: Introduce a key other Owners have given to work in a value chain.

2.4.2. Value Chain Creation Form

Like Company, Value Chain also has a display for visualising and editing content. First, an Owner must create a value chain from the map interface via a button on that screen. The following form will pop up:

Table 3: Value Chain Creation Form

Name	Type	Mandatory(M) /Optional(O)	UI Element
Value Chain name	String	M	Textbox
Value Chain product	- (1 or more)	M	Click in display
Value Chain Description	String	O	Textbox
Link name (Website, Twitter, etc)	String-URL	O	Textbox Textbox
Mail	String	O	Textbox
Phone number	String	O	Textbox
Logo	Image	O	Submit file
Company Selection	- (1 or more)	O	Search browser

Value Chain name: name shown in value chain display.

Value Chain product: the objective of the value chain. The companies involved must have at least one module with a title including this field.

Value Chain description: a general description of it.

Link name (Website, Twitter, etc): same as other forms.

Mail and Phone number: the main contact of the value chain.

Logo: logo displayed for value chain.

Company Selection: A list of companies involved in the value chain. Companies in this list should receive an invitation, and if it is accepted, they will form part of the chain. There will be an editable display where the Owner of the value chain chooses who has access to each module of the chain to edit it.

2.4.3. Map, Company and Value Chain Display

The **Map Display** is the platform's main screen. Every user will start from this viewport. It will consist of a simple map divided by countries.

The working principle is a European map with filters on one side (filter by value chain or product) and a browser to search by name. The user may also zoom to a country or maybe click directly on it to zoom. When the user sees a country or a region on the map, the companies will display as simple icons, and the user can click on one of them to pass to the Company display.

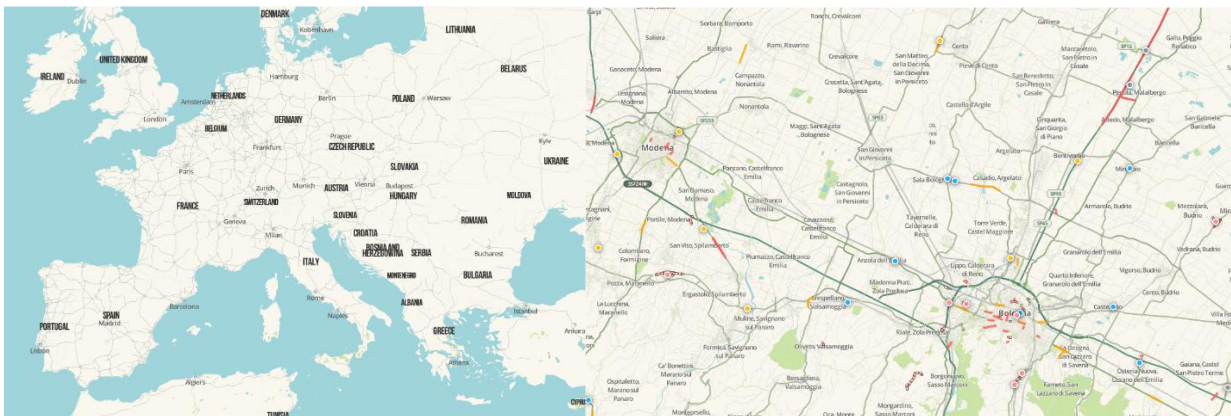


Figure 5: Map Display

As a reference, there are some apps like Waze or Maps:

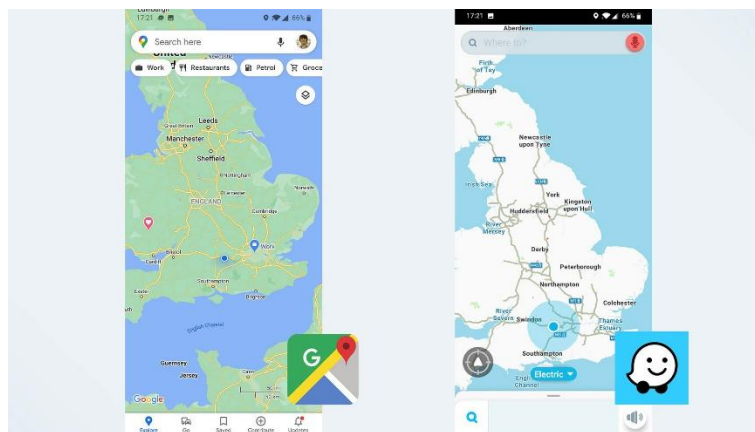


Figure 6: Google Maps and Waze displays

At first, any user will see the **map display** showing the information of each company. Stakeholders and Owners without companies don't have representation, so they won't be displayed on the map. Each company would be represented in the corresponding countries and approximative coordinates if the address was given. The

user can access the desired company by clicking on a country and later zooming. Additionally, a company can be searched by a browser, and there is a filter of the display by sectors, too.

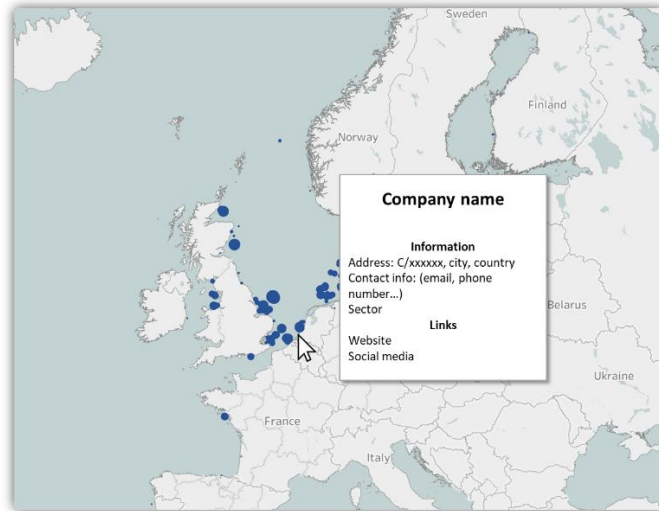


Figure 7: Map display with company information

After zooming in the area multiple companies display in the map. By clicking on one of them, the user will see public information, see private information if he has permission and edit information if he has permission.

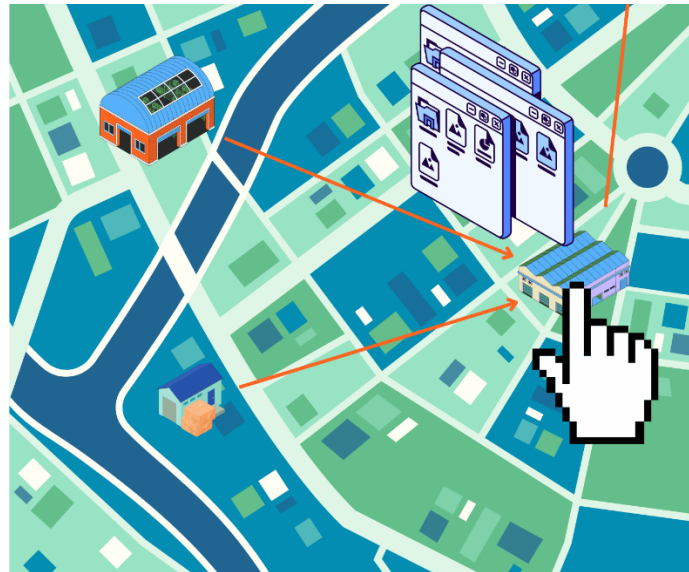


Figure 8: Mouse over a company showing most relevant data and the relation with other companies

Once a company is clicked, the company display appears, and modules become accessible to be seen or created/modified if the user has permission.

The **Company Display** will allow the user to edit the Company. This display is similar to a character creation in a video game. This part is where modules can be accessed, and the main information is displayed.



Figure 9: Company Display

It is composed of:

- The name on top.
- A simple representation of the company.
- A simple map with the countries where the company is present.
- A button to access the contact information.
- A panel or display where the modules are shown.

This screen also allows the user to access the modules. Some parts of the company representation will be clickable, and they will show the corresponding module. The standardized modules will have a standard screen location, while the custom modules will have a customizable screen location and aspect.

Clicking on a module makes the user enter the module display where the form is edited and filled. All displayable rows in the generic form will appear in the company display and be edited there similarly as done on a screen of a PowerPoint. If no modules are created, there will be a toolbar where the user can choose which modules want to create.

In relation to the **Value Chain Visualisation**, while the user is in the map display, he can see the value chains by placing the mouse on top of the selected chain, and when clicked, it enters in value chain display to edit it the same way it is done in the company display.



Figure 10: Value Chain Display

When the user selects a value chain and enters the value chain display, he will have the same view as the company display but with a graphic representation of the chain.

The concept is the same, but modules in the chain can include information from modules in the companies (like text, visual elements and variables).

2.4.4. My Administration page

When the user enters this page, a **list of his companies and value chains** is shown, and another list with the companies and value chains to which he has permission is also shown. Selecting one of them will open the editor of that company/value chain. **On this editor page, the Owner can create modules and edit information about other Owners' possessions (and his own possessions)** if permission is given. **The editor of a company/value chain can also be accessed via the map.** On this page, **permissions can be granted and denied** to other Owners of companies and value chains, too.

The **Company Editor page** can be accessed by selecting a company on the My Administration page, but also by selecting a company on the map display. On this page, the Company Creation Form fields can be edited again, and something very important can also be done: **creating modules.**

The **Generic Form to create a module** also appears when a user with permission is in the **Company Display** and wants to create a module. It is adaptable to all user desires. This is the key tool for module creation, that allows the user to not only create business, social or LCA modules, but also new custom modules. Its concept is to ensemble nearly every module needs in the same page.

Before using it to create a module, the user should fill out a basic pre-form to define the module that is being created.

Table 4: Module Definition Form

Name	Type	Source	Mandatory(M) / Optional(O)	UI Element
------	------	--------	----------------------------	------------

moduleName	String	User Input	M	Textbox
modulePhoto	Image	User Input	O	File selector
description	String	User Input	O	Textbox

moduleName: Name of the module that will be displayed in the generic form.

modulePhoto: Image (picture, logo, icon...) of the module.

description: Description of the module that doesn't appear in the generic form but in the company display afterwards and will be editable.

Once this information is given the generic form will appear with the moduleName on top. This generic form is composed of three main columns and scrollable rows. At the beginning, there will be just a void row. If the user fills one of them, a new row will be created void, and this process repeats indefinitely.



Figure 11: Module preview

The three types of columns are “Text Column”, “Display Column” and “Attribute Column” (from left to right in the image) explained below. None of them is mandatory to fulfil, and depending on the inputs given, there will be a different working principle. As long as one of the columns is filled, the row is considered completed, so a new row will appear.

The eye button is a dropdown that lets the user decide if the row will be visible in the company display, in the module display or just invisible for unauthorised users. Rows should be:

- Added: There should always be a void row for the user to fill if desired.
- Editable: If the module is reopened, the user can modify this form.
- Deleted: The user can suppress all columns of a row; if that row is not the last one, it disappears.
- Scrollable: Rows can move up and down for sorting reasons.
- Concealable: All rows can be invisible to unauthorised users.

Note: If a user deletes a row whose variable (attribute column) is a dependency of a variable of another row, that other row can't calculate its attribute column; therefore, this row should return a null value for its variable.

The **Text Column** is designed to capture plain text inputs. The goal is to display this text in the **company display** or **module display** for marketing or explanation purposes. This column allows users to enter textual information with optional syntax for formatting.

Table 5: Text Column Form

Name	Type	Format	UI Element
text	String	Plain text + syntax*	Text box

- **Name:** The identifier for the text column.
- **Type:** Specifies the data type, which is a string for text columns.
- **Format:** Accepts plain text with optional syntax for advanced formatting.
- **UI Element:** A text box is used for user input.

***Syntax:** The text field supports Markdown syntax for formatting and includes the ability to incorporate variables from the attributes section by prefixing them with an underscore. Additionally, a graphical user interface (GUI) is provided for users who prefer not to use Markdown syntax.

- **Markdown Syntax:** Allows formatting such as bold, italic, headings, lists, and links.
 - Bold: ****bold text****at
 - Italic: **italic text**
 - Link: **[link text](https://example.com)**
 - Headings: **# Heading 1, ## Heading 2**
 - Lists: - **item** (unordered), **1. item** (ordered)
 - Equations: $\$0 = e^{\{i\pi\}+1}$
- **Attribute Variables:** Display values from the attribute section using an underscore.
 - **Example:** **_attributeName** will display the value of **attributeName**.

- **GUI for Formatting:** Provides buttons and tools to apply formatting without needing to know Markdown syntax. Includes options for bold, italic, headings, lists, links, and inserting attribute variables.

The **Display Column** is used to present information visually. This column allows users to include various visual elements such as images, videos and data series. Depending on the type of element selected, additional configuration options will appear.

Table 6: Element Addition Form

Name	Type	Source	Mandatory (M)/Optional (O)	Default Value	Dependencies (if exist)	UI Element
elementType	Selector	User Input	M			Dropdown list
elementTitle	String	User Input	O			Textbox
elementDescription	String	User Input	O			Textbox
elementFile	File	User Input	O			File selector
dataSeries	Array	User Input	O		Only if elementType is Data Series	File selector
dataSeriesType	Selector	User Input	M		Only if elementType is Data Series	Dropdown menu
visualizationType	Selector	User Input	O		Only if elementType is Data Series	Dropdown list
xlabel	String	User Input	O	Title of the first X column	Only if visualizationType is Plot	Textbox
ylabel	String	User Input	O	Title of the y column	Only if visualizationType is Plot	Textbox
plotTitle	String	User Input	O		Only if visualizationType is Plot	Textbox

addVariableValues	Char Float chain Yes-No	User Input	M	variableName - No	Only if elementType is Data Series	Input
Times	Date chain	User Input	M		Only if dataSeriesType is Temporal	Input
Category	Char	User Input	M		Only if dataSeriesType is Categorical	Textbox

- **addVariableValues:** The user can introduce a numerical set of values and assign the variable's name to the set. It is also possible to specify whether the values are percentages (the default value is Not Percentage). It is mandatory to introduce at least one variable if the elementType is Data Series.
- **dataSeriesType:** It can be Numerical, Categorical or Temporal. If it is Numerical, the variables x, y, z, etc can be introduced via the **addVariableValues** entries. You can introduce as many variables as you want, but for the plot, you must select the x and y variables that will be displayed in the axes. If it is Categorical, you must introduce a chain of categories in the **Category** entry, and their values in the same order in the **addVariableValues** entry. The plot types for this data series are Bar Plot and Circular plot. If the Data Series is Temporal, the user must provide the values of the variables in the **addVariableValues** entry and the times in the **Times** entry.
- **visualizationType:** Its values will depend on the Data Series Type. If it is Categorical, the visualisation can be with Bar and Circular graphics. If it is Temporal, it can be with Lines, Bars, or a combination of them. If it is Numerical, the visualisation will be with an X-Y plot.

This **Attribute Column** will take string inputs from the user in a concrete format and store them in the program memory as variables. It will also accept Sympy expressions to calculate other variables automatically.

Table 7: Attribute Column Form

Name	Type	Format	UI Element
variable	String	<varName>:<value>	Textbox
expression variable	String	<varName>:<expression>	Textbox

All variables will be accessible in the text box by using an underscore before the variable name or being used in an expression in this column to calculate other variables. The variables can support Booleans, floats and strings (including URLs).

This adaptable structure will allow the user to customise the module as wanted. The idea is to propose in this form normally used variables and structures that could automatically fill important variables like

“nEmployees”, “netIncome” or “annualProduction” that will be stored in the respective class (Business, Social, LcaBase).

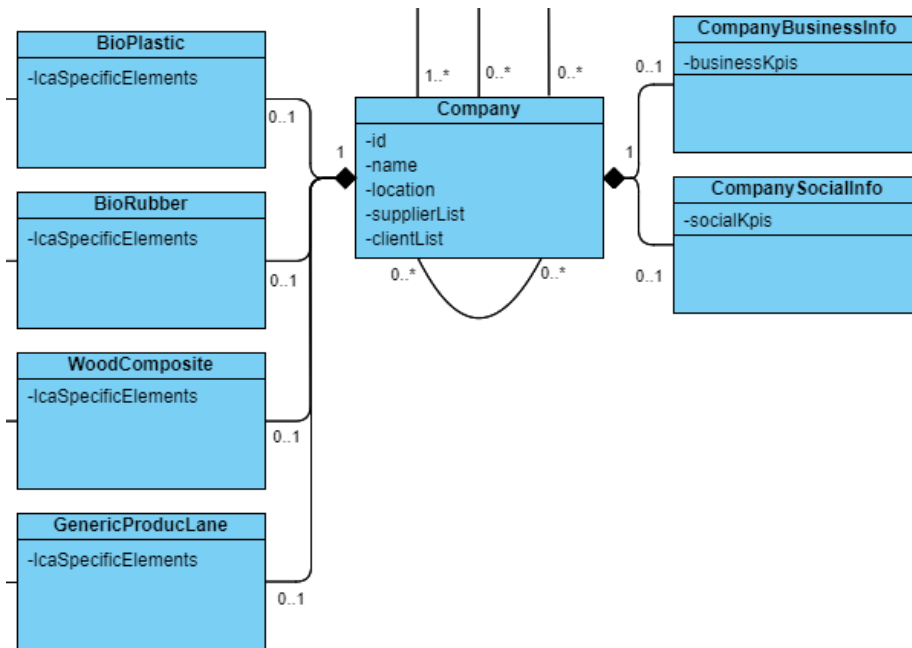


Figure 12: Relation of Company with other objects

Apart from the generic form, there will be some templates to fill standard modules and commonly used tools. These are **business form**, **social form** and **LCA form**.

The **business form** will be composed of two separate parts:

1. The first one will be in charge of taking all numerical inputs from the user. This information will be used to create the platform's logic, mainly KPI calculations but also database research and display modifications.

The idea is to create an adaptable and enjoyable form, so visualisation is key. In the first step, the user will see a simple and natural background with just a simple textbox input. From there, each input introduced will span a growing tree so that the user will build it. Depending on the inputs, one or another part will span. The dependencies of the inputs are studied in the diagram below.

The images below help to visually understand the idea.



Figure 13: Business module display

2. On a second screen, the user can upload text, images/videos, and values used in this module to display them in the company display. This working principle is nearly identical to the generic form so that it can be reused.

On the other hand, there are some guidelines for performing a module for the company's **social analysis**. The module will already have prepared displays. These are the Dissemination and Communication forms:

Table 8: Paper Section Form

Name	Type	Source	Mandatory(M) /Optional(O)	Default Value	Dependencies (if exist)	UI Element
(PaperT) Paper title With link	Float	User Input	O	-		Textbox
(Paperfig) Photo (not of the actual paper)	Fig	User input	M	-	If paper is introduced	Fig

Table 9: Conference Section Form

Name	Type	Source	Mandatory(M) /Optional(O)	Default Value	UI Element
(CDoc) Paper title With link	String	User Input	O	-	Textbox
(CVideo) Video of the conference	Video/link (to YouTube)	User input	O	-	Video/link
(CSlide) Presentation of the conference	Slide	User input	O	-	Fig/link

Table 10: Link Section Form

Name	Type	Source	Mandatory(M) /Optional(O)	Default Value	UI Element
(Mlink) Name of the social media with logo	String	User Input	O	-	Textbox
(Mlogo) Logo	Figure	User Input	O	-	Figure

Table 11: Human Skills Form

Name	Type	Source	Mandatory(M) /Optional(O)	Default Value	UI Element
(WorkshopT) Workshop title	String	User Input	O	Occupational safety	Textbox
(WorkshopV)Video	Video/link (to YouTube)	User Input	O		Video/link
(WorkshopS)Slides	Link	User Input	O		link
(WorkshopD)Description	String	User Input	O		Textbox

Another default module is the **Simplified Life Cycle Assessment (LCA) module** developed for the Greenloop platform. The module allows users to evaluate the environmental impacts of their products or processes in an accessible and efficient manner.

The objective of the simplified LCA module is to provide users with an intuitive tool to perform preliminary life cycle assessments, facilitating informed decision-making regarding the sustainability of products and life cycles within the project.

The design of the module consists of the following components:

- **Backend Database:** The Ecoinvent database is integrated into the backend, providing a comprehensive inventory of environmental data and processes.
- **Brightway2 Code:** A Brightway2 script is implemented to execute all the necessary LCA functionalities. This code handles the calculation and analysis processes based on user inputs and selected methods.
- **User Interface:** The user interface is designed to be intuitive and user-friendly, consisting of several key elements:
 - **LCA Calculator:** This is the main feature of the interface and includes the following tables:
 - **Process Input Table:** Users can input processes on the first cell of each row using a browser that searches through the Ecoinvent database. This allows for the easy selection and insertion of relevant processes into the LCA model.

Table 12: Process inventory

Materials				
Insert the name of the human processes for your life cycle	Product name	Location	Amount	Units
Polyester-complexed starch polymer production	Polyester-complexed starch polymer production	GLO	0.5	kg
Structural timber production	Wood chips, dry, measured as dry mass	RER	0.5	kg
Search...				

The user must write a keyword, and the browser will display a list of possible processes related to the keyword. The user chooses the desired process and inserts the amount in the third cell of the row. Once the last row is filled, another empty row appears.

- **Energy Demand Table:**

Table 13: Energy sources inventory

Energy sources				
Insert the name of the energy sources for your life cycle	Product name	Location	Amount	Units
Market for electricity, high voltage	Market for electricity, high voltage	GE	48.02	kw/h
Search...				

This table works in an identical manner to the Process Input Table, utilizing the same browser and accessing the same Ecoinvent database. Although it does not restrict the selection to only energy demand processes, it is intended for users to input energy demand processes specifically. This expectation is set to maintain organization and ensure a clear focus on energy consumption within the assessment.

- **Impact Categories Table:** Users can select from a list of 18 impact categories to include in the assessment. This table facilitates the customization of the analysis according to specific environmental concerns.

The user will choose categories by clicking a checkbox in each row and scrolling through the list to avoid displaying the entire list on the interface.

Table 14: Impact category list

Choose the category for your LCA	Units
'ReCiPe 2016 v1.03, midpoint (H)', 'acidification: terrestrial', 'terrestrial acidification potential (TAP)'	kg SO eq <input checked="" type="checkbox"/>
'ReCiPe 2016 v1.03, midpoint (H)', 'climate change', 'global warming potential (GWP1000)'	kg CO eq <input type="checkbox"/>
'ReCiPe 2016 v1.03, midpoint (H)', 'ecotoxicity: freshwater', 'freshwater ecotoxicity potential (FETP)'	kg 1,4-DCB-Eq <input checked="" type="checkbox"/>

The complete list of available impact categories is:

- Acidification: terrestrial
- Climate change
- Ecotoxicity: freshwater
- Ecotoxicity: marine
- Ecotoxicity: terrestrial
- Energy resources: non-renewable, fossil
- Eutrophication: freshwater
- Eutrophication: marine
- Human toxicity: carcinogenic
- Human toxicity: non-carcinogenic
- Ionising radiation
- Land use
- Material resources: metals/minerals
- Ozone depletion
- Particulate matter formation
- Photochemical oxidant formation: human health
- Water use

- **Results Vector Table:** This table displays the results vector after the LCA calculation, showing the environmental impacts for the selected processes and categories.

Table 15: Table of results

RESULTS	Amount	Units
'ReCiPe 2016 v1.03, midpoint (H)', 'acidification: terrestrial', 'terrestrial acidification potential (TAP)'	0.673453	kg SO eq
'ReCiPe 2016 v1.03, midpoint (H)', 'ecotoxicity: freshwater', 'freshwater ecotoxicity potential (FETP)'	0.021321	kg 1,4-DCB-Eq
'ReCiPe 2016 v1.03, midpoint (H)', 'eutrophication: freshwater', 'freshwater eutrophication potential (FEP)'	0.4565234	kg P-eq

Link to ecoinvent website: a link to the ecoinvent website so that users can easily find general information about any process for all parts of the life cycle, from production to disposal, without needing a license.

Additional Features: Apart from the LCA calculator, the interface includes buttons that direct users to several additional pages:

- **Contribution Analysis Page:** This page displays a graph of the contributions of processes and a graph of the elementary flows that have the most impact on the results for each impact category. There is also an option to display the lists of process contributions and elementary flows in tabular form.

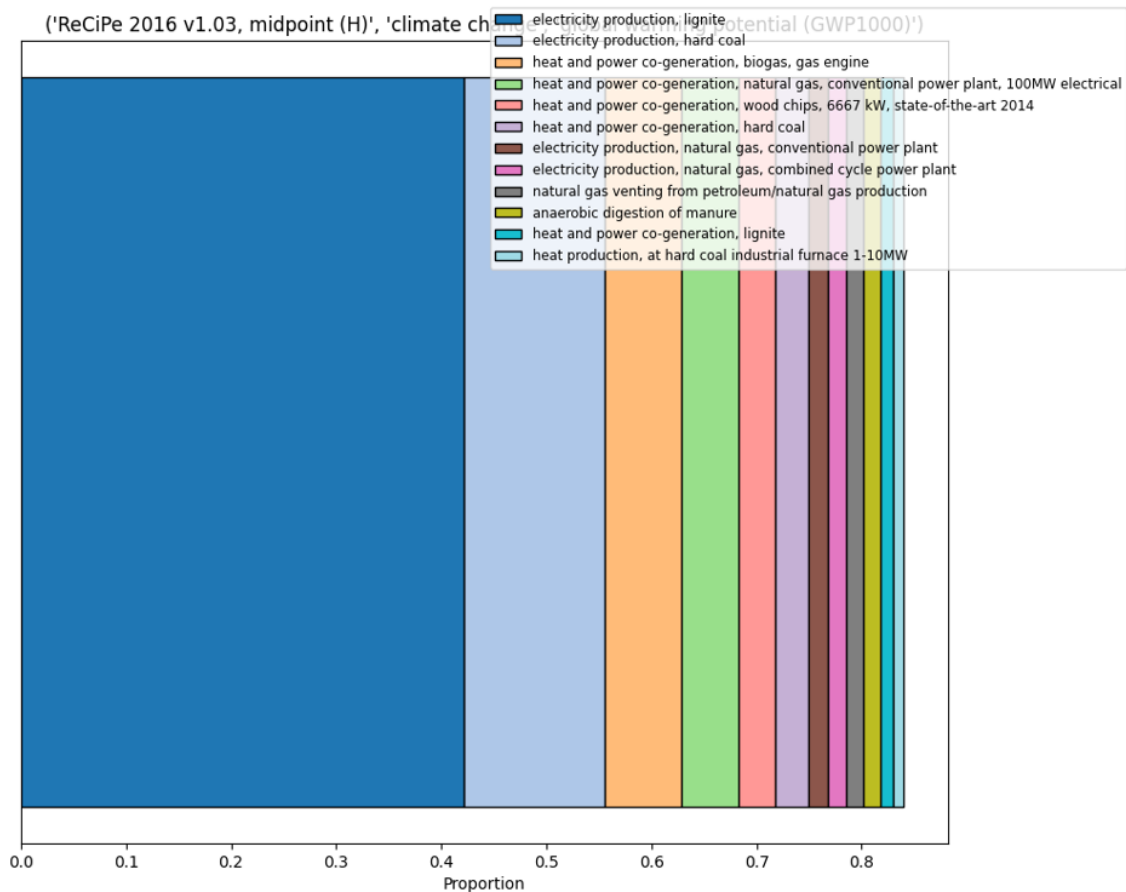


Figure 14: Graph of contributions

- **Global Sensitivity Analysis Page:** This page performs global sensitivity analysis using the Saltelli method. It helps users understand the sensitivity of the LCA results to variations in input data, providing insights into the robustness of the assessment.

This is an example of the global sensitivity analysis results for the marine eutrophication category:

First-order Sobol indices (S1): These indicate the direct contribution of each variable to the output variance.

1. ‘polyester-complexed starch biopolymer production’: 0.9996 (99.96%)
2. ‘market for electricity, high voltage’: (0.0276%)

3. ‘structural timber production’: 0.000047 (0.0047%)

Total Sobol indices (ST): These include first-order effects and all interactions with other variables

1. ‘polyester-complexed starch biopolymer production’: 0.9909 (99.09%)
2. ‘market for electricity, high voltage’: 0.0098 (0.98%)
3. ‘structural timber production’: 0.00003 (0.003%)

- **Periodic Life Cycle Assessment Page for sensors:** This page allows for periodic life cycle assessments based on data from energy demand sensors in a factory. It enables continuous monitoring and assessment of environmental impacts over time, facilitating proactive sustainability management.

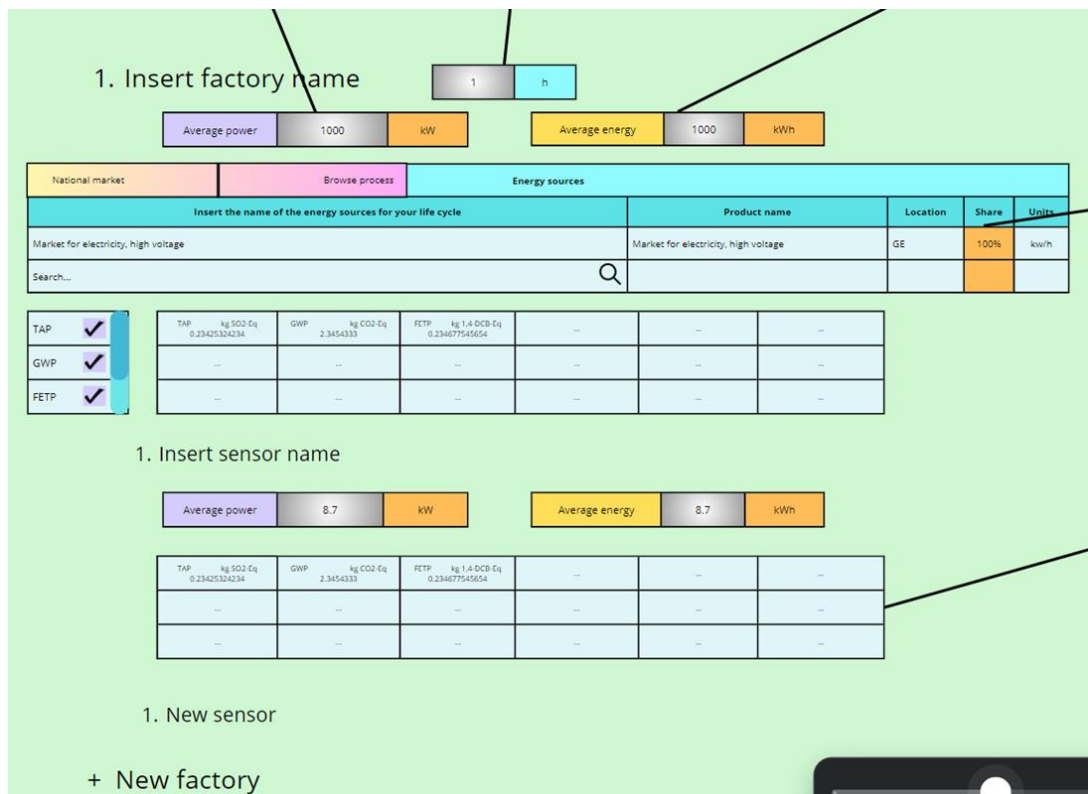


Figure 15: Sensor page

The user specifies the time interval for the environmental impact estimations, which applies to the entire factory. They also input the average power demanded by the factory during this interval. This power can be a constant value or derived from a function, such as the sum of the average powers recorded by all sensors.

The power is then multiplied by the time interval to calculate the energy consumed by the factory within that period. Based on this energy consumption, the country’s energy mix, and

the selected impact categories, an LCA is performed, and the results are displayed in tabular format.

To estimate the contribution of each machine monitored by a sensor to the overall environmental impacts, the results matrix is multiplied by the ratio of the power detected by the sensor to the total power of the factory.

Help Button: Both the calculator page and the sensors page feature a help button. When clicked, it provides descriptions of the elements on the page, assisting users in understanding the functionality and purpose of each component.

Text for the help button of the calculator:

- o Table of processes: Search the processes via the browser. You have to write a keyword and the browser will display a list of possible processes. Choose the quantities of the product.
- o Table of energy processes: Search the energy demand processes via the same browser. Choose the quantities.
- o Abbreviation expander: Displays the full name of a geographical location via a dictionary
- o Link toecoinvent webpage: In theecoinvent database you can search information about any process without the need of a license.

Text for the help button of the sensor page:

- o Period (h): time interval between LCAs. It can be 1 h, 5 h, 24 h...
- o Average power (kW): it displays the average power demanded by the factory in the time interval
- o Average energy (kWh): it displays the energy demanded by the factory in the time interval
- o Energy sources: Table that lets you choose energy source processes from the database and modify their shares
- o Table of impact categories: Lets you choose between the 18 categories (the abbreviations appear in the table of categories of the normal calculator and the full names can be shown upon placing the cursor over the cells)
- o Matrix of results: Shows the results of the LCA based on the selection of categories and the energy sources
- o Average power for sensors (kW): it displays the average power demanded by the sensor's machine in the time interval
- o Average energy for sensors (kWh): it displays the energy demanded by the sensor's machine in the time interval
 - o Matrix of results for sensors: Shows the results of multiplying the matrix of results of the factory by the average power of the sensor divided by the factories average power.

Tools

Also, there will be a usual template for some **useful tools** that will behave like the modules: **the Survey and Porter Value Chain Forms**.

With the Survey Form, the user can make his own surveys, create his own questions and allow different types of answers from the other users. The idea is that this form creates a questionnaire for any user who enters to see the company or a module. It can be done via a link to Doodle.

Table 16: Add Survey Form

Field	Type	Mandatory(M) /Optional(O)	UI Element
Survey title	String	M	Textbox
Skippable	-	M	Yes-No selection

Table 17: Add Question Form

Field	Type	Mandatory(M) /Optional(O)	Dependencies	UI Element
Question redaction	String	M		Textbox
Answer requested type	-	M		Dropdown menu (text, number, code, multiple selection, date, long text...)
Option text	String	O	If Answer req. is Multiple Selection	Input box
Option number	Float	O	If Answer req. is Mult. select.	Input box
Date	mm/dd/yyyy	O	If Answer req. is Date	Date menu
File	-	O	If Answer req. is File	Submit Button
Add images	-	O		Submit Button

On the other hand, the user will be able to add a **Porter Value Chain**. A PNG image will be displayed and available as an image anywhere. If the user wants to add an additional box, he can do that by introducing a Title and a Description text with the **addBox** button. He must select if the box will be in the primary activities (horizontal) or secondary activities (vertical) sections with a dropdown menu. If a field is not introduced, the figure will not display that part. That’s why all fields are optional.

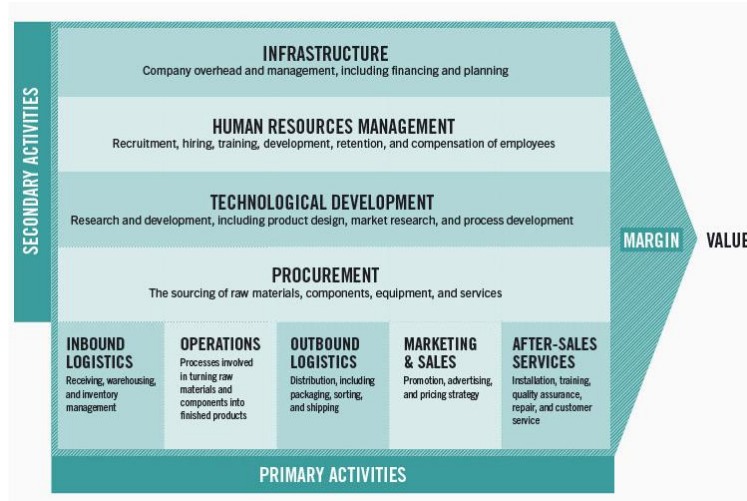


Figure 16: Porter Value Chain display example

Table 18: Porter Value Chain Form

Field	Type	Mandatory(M) / Optional(O)	UI Element
Inbound logistics	String	O	Textbox
Operations	String	O	Textbox
Outbound logistics	String	O	Textbox
Marketing and sales	String	O	Textbox
After-sales services	String	O	Textbox
Infrastructure	String	O	Textbox
Human resources	String	O	Textbox
Technology	String	O	Textbox
Procurement	String	O	Textbox
addBox	Button	O	Dropdown menu
	Char		Textbox
	Char		Textbox

Outside of the Generic and default Forms, another accessible page from the My Administration page is the **Value Chain Editor**. This page can be accessed by selecting a value chain on the My Administration page, but also by selecting one on the map display. On this page, the Value Chain Creation Form fields can be edited again, and **the user can create modules** the same way they can be created for the companies.

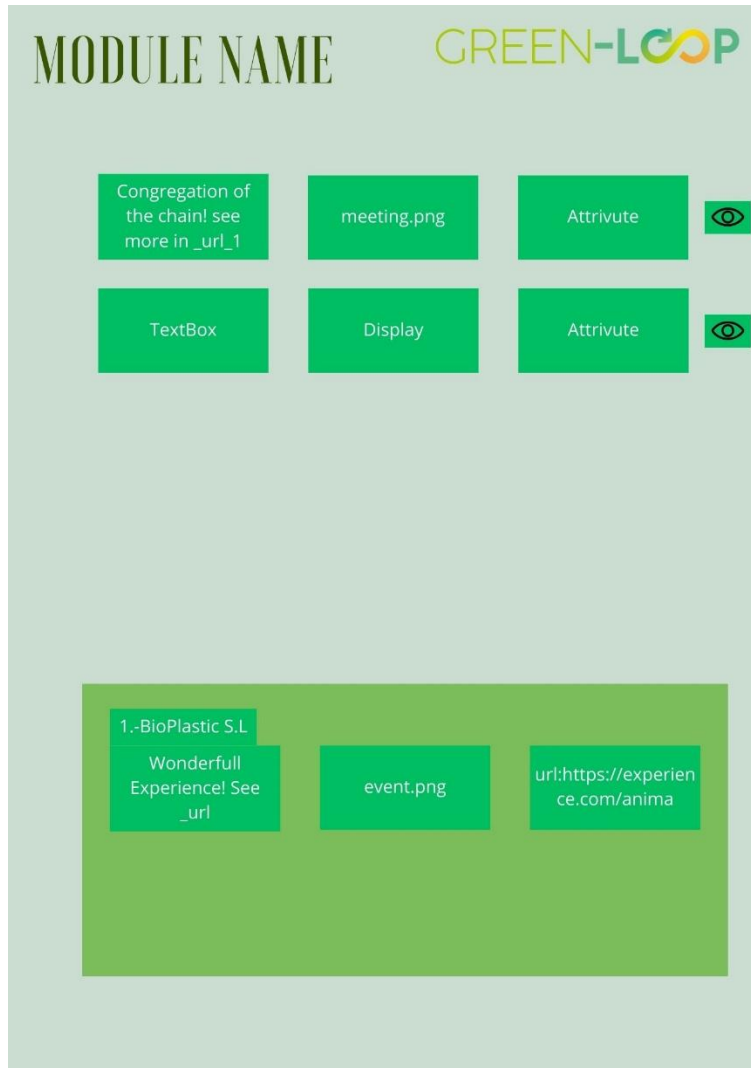


Figure 17: Value Chain Module Preview

The **Generic Form for Module Creation in Value Chain Objects** has the same structure but can access other business variables using slightly different operation logic to avoid confusing variables with the same name and avoid disorder. These company variables will be shown below in another market area and listed by number.

2.5. Granting and denying permission

Owner is the main role in the platform, and he is the only one that can grant or deny permission, and only to another Owner.

An Owner has always full permit over his possessions like his own company or his own value chain, but this Owner 1 can let an Owner 2 edit his value chain, his company or just a specific module. Value chain, Company and each created module should give the option to the user for creating collaboration groups to work. It will be like Google Groups, where the user may find a list of all modules in a value chain or a company and can invite someone else to edit just a module or all modules.

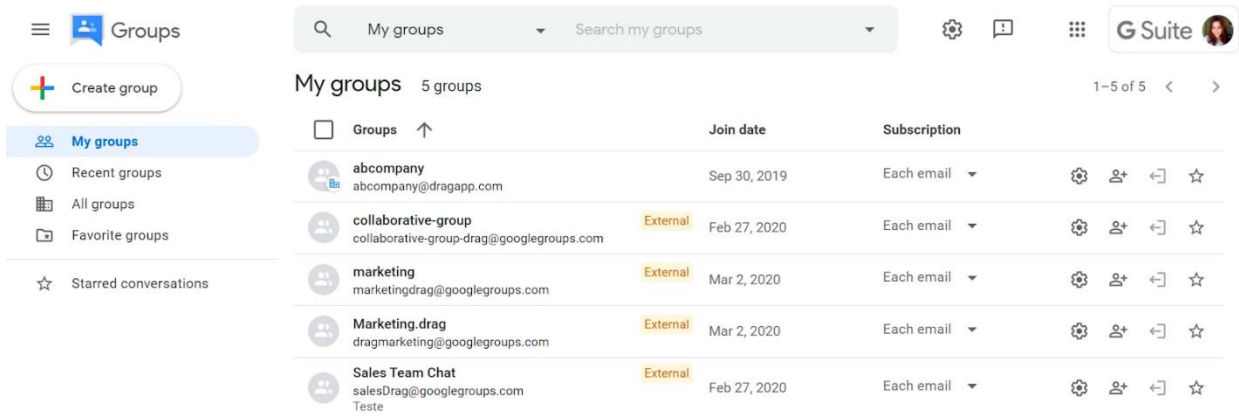


Figure 18: Google Groups Display

In this scenario, there would be just two roles in a group, the Owner 1 would be the untouchable owner and editor, and the others would be just temporary editors. Google groups roles of owner, manager and member will be maintained to let Owner 2 admin the group if Owner 1 considers it.

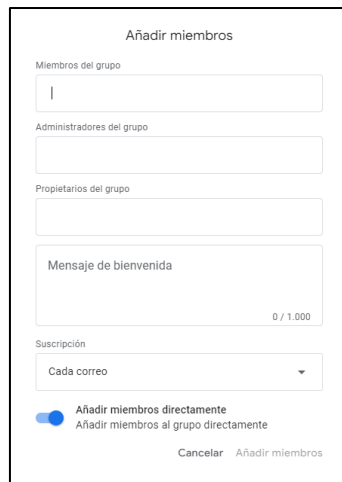


Figure 19: Google Groups Add New Member Window

All members and Admins can be deleted (deny permission), but the Owner 1 can never be deleted.

2.6. Technologies overview

To realise the implementation of the GREEN-LOOP platform architecture presented on the previous section, several technologies have been evaluated, and the more suitable ones have been settled upon for development of the platform.

One important factor to consider when talking about a microservices-based architecture is that no language or technology restriction be applied between them. This means that each microservice can be implemented independently of the others since the interrelations between them, done via their exposed APIs, completely abstract their internal workings from needed to be exposed.

At this point in the project’s lifecycle, the most relevant technologies selected for implementation are the following:

- The Frontend application will be based on Microsoft’s **.NET 6.0** technologies, in particular the **Blazor open-source framework** for web development.
- The microservices are being developed using the **Python** programming language and its set of related tools, due to their accessibility, openness, and ease of use.
 - Both **Flask** and **FastAPI** have been explored to provide the REST API capabilities of the microservices. FastAPI has been favoured due to its capability of handling asynchronous API calls natively, which can prove beneficial when dealing with complex operations on the microservices.
- For distributed file storage, **SeaweedFS** has been integrated into the platform, providing a scalable and efficient solution for managing large volumes of data. Its compatibility with Amazon S3 ensures seamless interaction with existing cloud infrastructure, while its high performance and low latency make it an ideal choice for handling the diverse storage needs of the microservices. SeaweedFS’s ability to efficiently manage both small and large files allows the platform to maintain flexibility and performance as it scales.
- To facilitate real-time data access and ensure efficient communication between the various modules of the GREEN-LOOP, **Apache Kafka** has been implemented as a core component of the microservices architecture. Kafka is a distributed data streaming platform that enables the processing of large volumes of information with low latency, making it a robust and scalable alternative to traditional REST APIs when real-time communication is required.
 - Within the GREEN-LOOP context, Kafka is used to handle continuous data streams and ensure reliable and orderly message delivery between microservices. This is particularly important in modules where minimal latency and high data availability are critical, such as those handling real-time events or requiring precise synchronization of information across different system components.
 - Additionally, Kafka’s ability to store and process data in a distributed manner allows microservices to access and process information efficiently, even in high-concurrency scenarios. This not only enhances the overall system performance but also provides greater flexibility in data management, as microservices can consume and process messages at their own pace, thereby decoupling data generation from consumption. The implementation of Kafka in GREEN-LOOP ensures that the system can scale horizontally and handle increases in workload without compromising data integrity or processing speed.

- **JavaScript** plays a crucial role in enhancing the interactivity between the server and client in the GREEN-LOOP platform, particularly in conjunction with pages developed using Blazor. As a versatile, client-side scripting language, JavaScript allows for dynamic content updates and real-time interactions without the need for full page reloads. This capability is especially valuable in a Blazor environment, where JavaScript can be seamlessly integrated through JavaScript Interop, enabling the platform to leverage complex client-side operations while maintaining the robustness of server-side Blazor components. This combination ensures a smooth user experience with responsive and interactive web applications that effectively bridge the gap between the server and the user interface.
- **OpenStreetMap** has been integrated into the platform to facilitate the visualization of companies within the GREEN-LOOP ecosystem. OpenStreetMap is an open-source mapping technology that provides detailed and customizable geographic data. By utilizing OpenStreetMap, the platform benefits from precise and flexible mapping capabilities, allowing users to view the locations of various businesses and resources in a user-friendly manner. The open nature of OpenStreetMap enables the platform to tailor the visualizations to specific needs, such as highlighting certain industries or regions, thus providing a powerful tool for analyzing and interacting with geographic data related to the platform's objectives.
- Containerisation technologies used are based on **Docker**, with Docker Compose as orchestrator.

As noted, the GREEN-LOOP platform is an on-going development and the current deliverable is considered a living document, so all technologies discussed are subject to change as the development continues. All changes and relevant additions will be noted in subsequent versions of the deliverable.

3. Development status

3. Development overview

Based on the work completed during the previous period concerning the architecture and security of the platform, the implementation of each component specified in Section 2 of this document has been started. This foundational work has laid the groundwork for the systematic development of the platform, ensuring that each module is built in accordance with the established architectural guidelines and security protocols. The focus during this phase has been on translating the theoretical framework into practical, working components that interact seamlessly within the overall system.

3.1. Entity Modeling and Code Generation in .NET

To implement the entities described in Section 2, scaffolding techniques in .NET have been employed. This process enabled the automatic generation of the necessary code, translating each entity from the diagram into corresponding classes with their specific attributes. These classes form the foundation for business logic and database interaction, ensuring that the code structure is rigorously aligned with the previously established conceptual design, thereby facilitating the overall development process.

Scaffolding in .NET is a powerful technique that automates the creation of data access layers and business logic based on data models. In the context of the GREEN-LOOP development, this tool has been instrumental in accelerating the creation of data access layers and business logic. By using scaffolding, classes were generated that not only reflect the entities and their relationships as designed in the diagram but also include pre-configured methods and properties that simplify common operations such as creating, reading, updating, and deleting records. This approach ensures consistency and accuracy in the implementation while reducing human error and speeding up development, allowing the team to focus on more complex and specific aspects of the system.

The following figure is a representation of the Company entity, detailing all its attributes and relationships with other entities. This diagram illustrates how the Company class is structured, including its properties and associations, reflecting its role within the overall system architecture.

```

public class Company : IEntity
{
    [Key] public long Id { get; set; }

    public DateTime Created { get; set; } = DateTime.UtcNow;

    public string Name { get; set; }

    public string? Description { get; set; }

    public string? Mail { get; set; }

    public string? Phone { get; set; }

    public string? Link { get; set; }

    public string? LogoPath { get; set; }

    public double Latitude { get; set; }

    public double Longitude { get; set; }

    public long? ValueChainId { get; set; }

    public ValueChain? ValueChain { get; set; }

    public List<Country>? MarketCountries { get; set; }

    public List<Variable>? Variables { get; set; }
}
    
```

Figure 20: Entity Company Class

3.2. Authorization and Authentication Using Identity in .NET

In the GREEN-LOOP platform, both authentication and authorization are crucial components to ensure secure access and management of resources. Authentication is the process of verifying the identity of a user, ensuring that they are who they claim to be, typically through credentials like usernames and passwords. Authorization, on the other hand, determines what an authenticated user is allowed to do within the system, based on their roles and permissions.

Using ASP.NET Core Identity, the platform benefits from a robust and flexible authentication framework that seamlessly integrates with existing .NET applications. Identity provides built-in support for user management, password hashing, token generation, and other security features, which significantly strengthens the security posture of the platform.

One of the key advantages of using Identity in .NET is the ability to implement role-based authorization policies. This approach allows the platform to enforce fine-grained access control, where users are assigned specific roles, and each role is associated with a set of permissions that define what actions the user can perform.

To implement this, a role-based policy has been created, as demonstrated in the PermissionMatrix class. This policy outlines different roles, such as Admin, Owner, Editor, Stakeholder, Guest, and User, each with a defined set of permissions. For example, the Admin role is granted full access (Permissions.All), while roles like Stakeholder and Guest are restricted to viewing public data (Permissions.SeePublicDataExternal).

This role-based authorization policy provides the platform with a strong security framework that not only ensures that users are authenticated correctly but also that they only have access to the resources and actions that are appropriate for their role within the system. This setup helps prevent unauthorized access and ensures that sensitive data is protected, while still providing flexibility in how different user roles interact with the platform.

Table 19: Users roles and permissions

Role	All	CreateEditDeleteOwned	SeePrivateDataOwned	SeePublicDataExternal
Admin	X			
Owner		X	X	X
Editor		X	X	X
Stakeholder				X
Guest				X
User				X ¹

3.3. Integration of OpenStreetMap for Data Visualization

The integration of OpenStreetMap (OSM) is currently being implemented within the platform to facilitate the visualization of geographic data, such as the locations of companies. OpenStreetMap is an open-source, collaborative mapping project that provides detailed and customizable geographic data. By leveraging OSM, the platform can display dynamic maps that allow users to interact with and analyze location-based information effectively. This integration enhances the user experience by providing accurate and up-to-date geographic visualizations that are essential for making informed decisions based on spatial data.

OpenStreetMap offers several key features that make it an ideal choice for this integration. It is a collaborative and open platform, meaning that anyone can contribute to the map by adding geographic information such as streets, buildings, parks, rivers, and other elements. Users can also correct errors, update data, and add local details that may not be present in other mapping services. OSM's data is free and unrestricted, making it accessible for use in a wide range of applications, from small projects to large commercial platforms. Additionally, the open-source nature of OSM allows for extensive customization, enabling users to create tailored maps, apply unique styles, and develop applications that utilize geographic data according to specific needs. OSM's flexibility and wide applicability across sectors like GPS navigation, urban planning, environmental studies, and academic research further underscore its value in projects requiring detailed and customizable geospatial data.

3.4. Platform Current Status

At the time of submission of this deliverable, the main development activities completed are as follows:

In the Backend, all necessary microservices have been started, their architecture defined, implemented, and made operational, with containerization based on Docker. The entire business logic has been implemented, including the scaffolding of entities and the addition of necessary operations to perform CRUD (Create, Read, Update, Delete) functionalities. Test APIs have been created and deployed, providing the foundation to incorporate the final algorithms and methods from other tasks. Additionally, these APIs have been secured with JWT authentication. Authorization and authentication mechanisms have also been implemented, ensuring that access control is managed effectively across the platform.

On the Frontend, the development of various modules is currently underway, with the project in a functional development phase. This progress lays a strong foundation for the continued integration and expansion of features as the platform evolves.

The basic user application architecture has been updated, and the existing backend APIs are accessible from the Graphics User Interface (GUI). User management capabilities have been developed and the JWT authentication schema is applied to the API communication, ensuring compatibility and security across all the architecture.

Below are some screenshots of the platform's sections. It is important to note that the platform is still under development, and the final version may differ from these images.

The following two images showcase the main page and the login section of the platform. These screenshots provide a glimpse into the current design and functionality, illustrating the user interface elements and the overall layout as it stands in this phase of development.

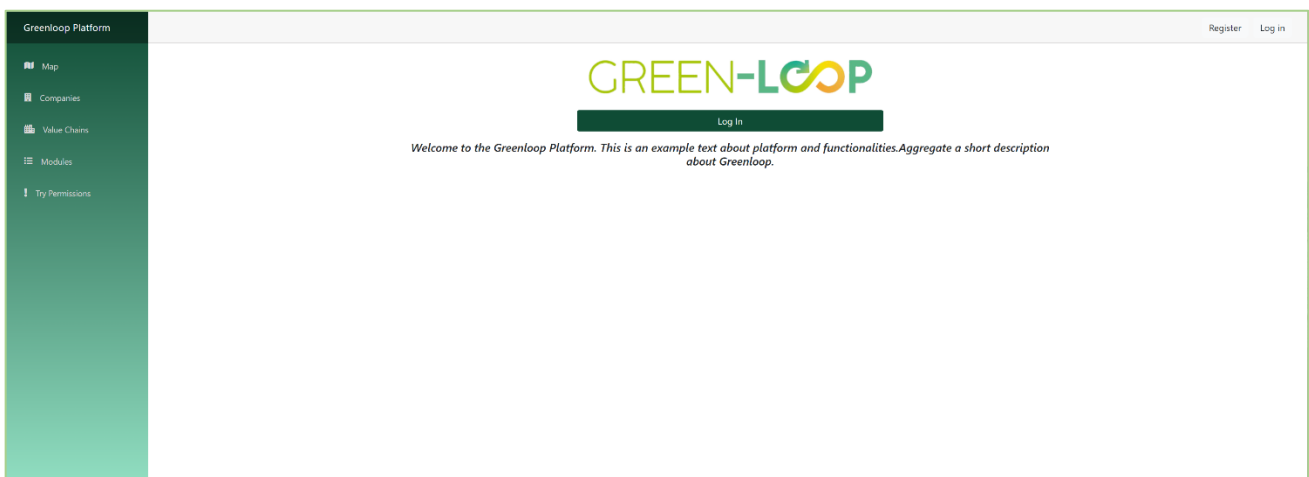


Figure 21: GREEN-LOOP Platform main page

Welcome to Greenloop Platform

GREEN-LOOP

Email

Password

Remember me?

[Sign in](#)

[New here? Register](#)

Figure 22: Login Page

The next two images depict the form for creating a new company and the company visualization page. These screenshots highlight the process of entering company details and how the platform displays the information, offering insight into the user experience when managing and viewing company data within the system

Hello, admin@webapp.com! [Log out](#)

Create company

[Download as JSON file](#)

Required properties(*):

- Title

Title *

Description

Company logo

Choose file

Location

[Edit location](#)

Figure 23: Example company creation form

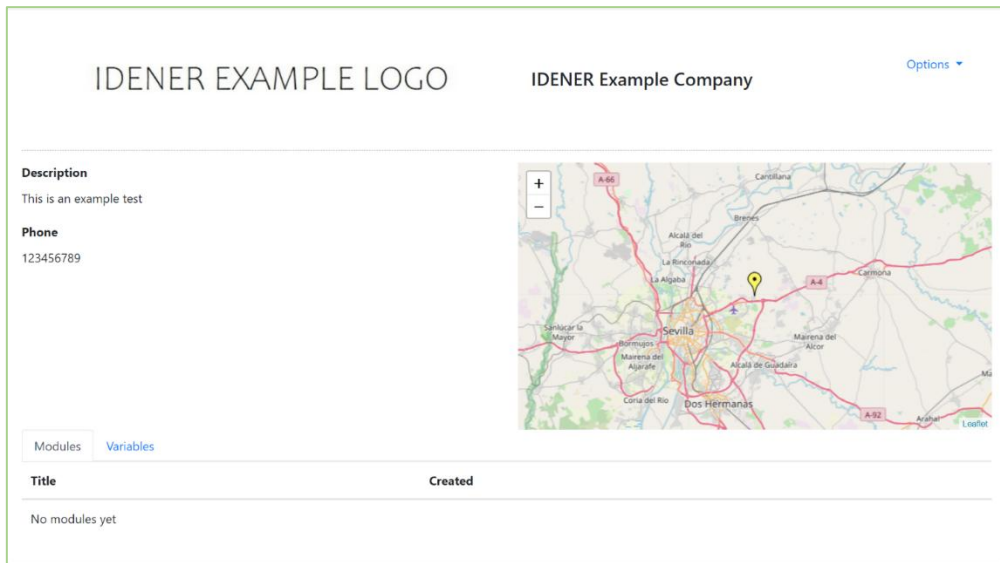


Figure 24: Company information page

The final image provides a view of the user and role management section. This section allows administrators to manage user accounts and assign roles, ensuring proper access control and permissions within the platform.

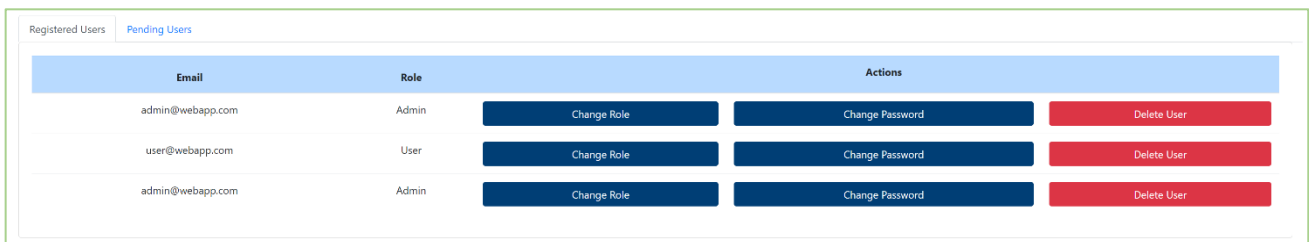


Figure 25: Users management page view

3.5. Platform access and deployment

The complete platform architecture is available to be deployed and tested via a common **GitHub repository**, access to which needs to be requested and accepted by IDE. The Models, backend Modules and frontend GUI are being developed on their own repositories, whose access is also restricted and granted in a case-by-case basis.

The GREEN-LOOP platform beta version will be accessible via the following URL: <https://greenloop.idener.ai>

To access the platform, please contact the IDE coordinator, who will provide you with a username and password. IDE is in the final stages of developing a registration page and a functional registration link will be provided, allowing users to create their own accounts for accessing the platform.

Note: These credentials are for testing purposes only and should not be used for operations in a production environment.

4. Conclusions

The GREEN-LOOP circularity platform development is an important factor to the success of the overall project, and the development overview contained in the current deliverable demonstrates that the task has made considerable progress towards ensuring a satisfactory outcome.

Platform Architecture: The architecture of the GREEN-LOOP platform has been designed to support flexibility, scalability and robust security, enabling seamless integration of diverse functionalities. The key aspects of the platform architecture include:

- **Modular Design:** The platform’s design is modular, allowing for the integration of various components such as real-time data acquisition, environmental performance assessments and business optimization tools. This modularity ensures that new functionalities can be added efficiently, supporting continuous improvement and expansion of the platform.
- **Security and Access Control:** Robust security measures have been integrated into the platform's architecture, including the use of ASP.NET Core Identity for user authentication and authorization. This guarantees the implementation of secure access, enabling control over user permissions and safeguarding confidential data.
- **Advanced Data Visualization:** The platform incorporates tools like OpenStreetMap to enhance data visualization, enabling users to interact with geographic data effectively and providing a dynamic user experience that supports informed decision-making.

Platform Development Status: The platform development has progressed significantly, with a focus on implementing core components in alignment with the architecture and security protocols established. The core entities were constructed using .NET scaffolding techniques to simplify the development of data access layers and business logic.

Authentication and authorization have been implemented through ASP.NET Core Identity, which offers strong security protocols and role-based access controls for efficient management of user permissions. Moreover, the incorporation of OpenStreetMap improves the capabilities of the platform for visualising data, so enabling interactive geographical analysis.

All crucial backend microservices have been created and implemented to maintain operational consistency across different environments, using Docker for the deployment. Continual frontend development is focused on improving user interaction and data management capabilities. At present, the platform is operational and undergoing ongoing development to enhance its capabilities and refine its current modules.