ECOLOOP

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Deliverable 2.1 Pilot site analysis and use cases, requirements and KPIs definition

**Funded by
the European Union**

Deliverable details

Title	WP	Version
D2.1 – Pilot site analysis and use cases, requirements and KPIs definition	2	V1.0

Contractual delivery date	Actual delivery date	Delivery type*	Dissemination**
September 2024 (M12)	September 2024 (M12)	R	PU

* Delivery type: R: Document, report; DEM: Demonstrator, pilot, prototype; DEC: Websites, patent fillings, videos, etc; DMP: Data management plan.

** Dissemination Level: **PU** - Public; **SEN** – Sensitive, limited under the conditions of the Grant Agreement.

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Version	Date	Person	Action	Status***
V0.1	05/04/2024	Klemen Peter Kosovinc (SETUP)	New Document	Draft
V0.2	09/05/2024	Klemen Peter Kosovinc (SETUP), Samo Lečnik	Revision of the first document	Draft

		(SETUP), Gašper Mis (SETUP)		
V.03	18/06/2024	All partners	Revision of the second version	Draft
V.04	24/06/2024	Klemen Peter Kosovinc (SETUP), Marko Hrovatič (SETUP), Gregor Gostinčar (SETUP)	Revision of the third version	Draft
V.05	30/06/2024	All partners	Revision of the fourth version	Draft
V.06	01/07/2024	Klemen Peter Kosovinc (SETUP), Gregor Lekan (SETUP), Ana Peternelj (SETUP)	Revision of the fifth version	Draft
V0.7	02/07/2024	Diego García-Casarrubios (ETRA)	T2.2 Methodology and content	Draft
V0.8	02/07/2024	Kevin Rodriguez (INDEREN)	T2.3 Methodology and content	Draft
V0.9	02/07/2024	Klemen Peter Kosovinc (SETUP)	Revision of the sixth version	Draft
V0.10	04/07/2024	Lola Alacreu (ETRA)	Revision of the seventh version	Draft
V0.11	10/07/2024	Klemen Peter Kosovinc (SETUP)	Revision of the eighth version	Draft
V0.12	01/08/2024	All partners	Revision of the ninth version.	Draft
V0.13	01/09/2024	Kevin Rodriguez (INDEREN), Jernej Zupančič, Jernej Jozič (UL), Ana Fernández, (GENIA), Sheila Sánchez Mínguez (ETRA)	Peer review	Draft

V1.0	17/09/2024	Klemen Peter Kosovinc (SETUP), Sheila Sánchez Mínguez (ETRA)	Final review	Final

***Status: Draft, Final, Approved, Submitted (to European Commission).

Keywords

Use cases, Requirements, Key Performance Indicators, pilot site analysis, user-centric approach, social impact, regulatory acceptance, economic feasibility assessment, collaboration, iteration process, use case monitoring, Horizon Europe, Open Access, Open Science.

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Executive Summary

This deliverable offers an overview of the tasks undertaken within the scope of T2.1 "Pilot site analysis and co-creation of project scenarios and UCs", T2.2 "Definition and consolidation of project requirements", and T2.3 "KPI identification and monitoring preparation". Its primary goal is to collaboratively engage all project partners to **define project Use Cases (UC)** to outline the specific tasks for fulfilling the four strategic objectives of ECOLOOP: Objective 1 "To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand"; Objective 2 "To optimise agricultural/forest waste management reducing the associated emissions"; Objective 3 "To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts"; Objective 4 "To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative business models (BM), financial instruments and policy recommendations". The defined UCs are crucial for the development of WP3 "Efficient production of renewable energy in agriculture and forestry sectors", WP4 "Renewable-based agricultural protocols and decision support tool for farmers and foresters" and WP5 "Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy". Furthermore, the goal of D2.1 is to identify **requirements** to ensure the successful implementation of the UCs and **propose Key Performance Indicators (KPIs)** for evaluating the economic, environmental, social and technical impact and acceptance of the proposed UCs.

Project partners have **employed various methodologies and tools to address the proposed objectives**. This process encompassed several stages, starting with analysing the pilot sites, then defining UCs using a template, identifying economic, environmental, and social impacts, revising UCs using a template, and progressively defining requirements leading to identifying KPIs.

The process of defining the UCs commenced with **analysing the pilot sites, which offered insights into the needs and objectives** of the Spanish, Bulgarian, Estonian, and Slovenian sites within the ECOLOOP project. **Initial UCs** were proposed in **Trello**, **aligning with the Key Exploitable Results (KER) of ECOLOOP** to provide an overview. Subsequently, the UCs were detailed using a **provided template**, and partners **evaluated their economic, environmental, and social impacts**. The UCs **underwent revision using a dedicated template**, resulting in the definition of **18 UCs overall**.

Definition of requirements in an **iterative manner** was performed in the **online tool Volere** for defining requirements. Partners inputted various details such as description, classification, type, priority, rationale, and acceptance criteria. Through **validation and revision phases**, partners interacted with these requirements to identify and resolve any

issues, ensuring consensus on the final list. In total, **91 requirements** were identified by ECOLOOP partners.

During the final stage, **KPIs** were **defined using a prepared template**. Project partners identified two categories: **general project KPIs and pilot site-specific KPIs**. The set of KPIs underwent thorough examination to ensure comprehensive coverage of economic, environmental, social, and technical impacts, as well as the acceptance of proposed UCs. In total, partners collected **37 KPIs**, which will be calculated within the ECOLOOP framework in the scope of WP7 Project impact evaluation and replication strategy.

In this deliverable, each pilot site compiled **extensive documentation encompassing pilot site analysis, UCs, economic, environmental, and social impact assessments, UCs revision, requirements, and KPIs**. A summary of each pilot site's contribution is outlined in chapters on Pilot Site Contributions and Analyses, Requirements and KPIs while the detailed documentation is available in the Annexes. This comprehensive outcome will underpin the ECOLOOP initiative, **establishing a robust and comprehensive framework for the deployment of ECOLOOP services and results**.

Copyright statement

1. Introduction

1.1. Purpose of the document

This deliverable outlines the key activities and outcomes from tasks T2.1 "Pilot site analysis and co-creation of project scenarios and Use Cases", T2.2 "Definition and consolidation of project requirements", and T2.3 "KPI identification and monitoring preparation". The primary objective is to collaboratively engage all project partners in defining the UCs, which will guide the specific actions needed to achieve the four strategic objectives of ECOLOOP: Objective 1 "To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand"; Objective 2 "To optimise agricultural/forest waste management reducing the associated emissions"; Objective 3 "To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts"; Objective 4 "To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative BMs, financial instruments and policy recommendations". The defined UCs are foundational for the development of WP3 "Efficient production of renewable energy in agriculture and forestry sectors", WP4 "Renewable-based agricultural protocols and decision support tools for farmers and foresters", and WP5 "Economic and social support for farmers' and foresters' engagement as renewable energy prosumers". The document also sets the stage for identifying critical requirements and KPIs to ensure the effective implementation and impact assessment of the UCs across economic, environmental, social, and technical dimensions.

1.2. Scope of the document

Project partners have employed various methodologies and tools to address the proposed ECOLOOP objectives. This process encompassed several stages, starting with the analysis of pilot sites, followed by defining UCs using a template, identifying economic, environmental, and social impacts, revising UCs using a template, and progressively defining requirements leading to the identification of KPIs. Each pilot site compiled extensive documentation encompassing pilot site analysis, UCs, economic, environmental, and social impact assessments, UCs revision, requirements, and KPIs. A summary of each pilot site's contribution is outlined in the Chapter on Pilot Site Contributions and Analyses, while the detailed documentation is available in the Annexes.

1.3. Structure of the document

The document is divided into the following chapters:

- **1. Introduction**: provides the basic information about the document, its objectives and general overview of ECOLOOP.
- **2. Methodology**: outlines the methodology and tools used to collect the input for UCs, pilot site analyses, requirements and KPIs from the project partners.
- **3. Pilot Site Contributions and Analyses**: overviews the contribution from each pilot site, encompassing pilot site analysis, UCs definition, economic, environmental and social impact and UCs revision.
- **4. Requirements:** overviews the requirements defined by all partners and pilot sites.
- **5. KPIs:** overviews the KPIs defined by all partners and pilot sites.
- **6. Conclusion:** provides the main conclusion and recommendation points of the document.
- **7. References and Acronyms**: provides information on the used sources and acronyms.
- **8. Annex I: Use Cases:** contains extensive documentation of the project UCs.
- **9**. **Annex II: Use Cases Revision**: contains extensive documentation of the project UC revisions.
- **10. Annex III: Requirements**: contains extensive documentation of the project requirements.
- **11**. **Annex IV: KPIs:** contains extensive documentation of the project KPIs.

1.4. ECOLOOP in a nutshell

Renewable energy solutions integrated in agriculture, forestry and agroforestry systems play a critical role in meeting the needs for electricity, heating, cooling, transport and waste and land management in rural areas. Therefore, Europe can advance efforts to lower greenhouse gas emissions, increase the adaptive capacity of farmers, foresters, and related enterprises, while contributing to circular economy in rural areas. The growing evidence for these benefits presents a compelling case for decision makers to devise policies and measures to accelerate the adoption of renewable energy in agriculture and forestry systems.

ECOLOOP's key contribution to decarbonise the EU society is to create an ecosystem to optimize the combination of different energy distributed sources, such as biogas, biomass, Agri-Photovoltaic (PV) and geothermal, meeting the local needs for electricity, heating, cooling, transport and waste and land management in rural areas, fostering regional development and creating benefits for farmers and foresters. The project solutions focus on promoting the reduction of carbon footprint in rural areas by means of the higher penetration of distributed Renewable Energy Sources (RES), self-consumption, and optimal agricultural/forest waste management, while creating positive effects in biodiversity and soil health and reducing the risk of groundwater contamination.

All the benefits provided by ECOLOOP solutions will be demonstrated in 4 pilot sites in Spain, Estonia, Bulgaria, and Slovenia, involving different forest and agriculture natural conditions (climate, soils), size and types of crops trees, management techniques, degree of mechanization, geographic location, and socio-economic factors, and considering the interaction of different types of energy sources.
To address this approach, ECOLOOP provides and demonstrates a set of 7 innovations:

ECOLOOP - biogas production

To define and develop the process to produce and upgrade biogas to biomethane, using locally sourced feedstocks from agricultural wastes. As well as, exploring benefits of the anaerobic digestion of agricultural wastes able to replace mineral fertilizers and the flexibility management to increase profitability of slow pyrolysis.

ECOLOOP - RES integration

To optimize the distribution and interaction of biomass, biogas, geothermal or agro-PV on different areas for the efficient use of energy.

ECOLOOP - soil health

To investigate and test three sustainable and economic processes to replace traditional fertilizers by other biobased products to protect soil health, biodiversity, and ground water quality. Those are:

- Treatment of digestate used as an organic amendment for crop fertilization.
- Bio-stimulants to increase the CO_2 uptake in forest plantations.
- Wood ash recycling for forest plantations on organic soils.

ECOLOOP - decision support system

To enable farmers to monitor, manage and control crop production remotely, while reducing energy consumption and carbon footprint, as well as production time and costs.

ECOLOOP - CO$_2$ sequestration

To assist forest and landowners to select the best tree species on the given soil type to maximise the CO_2 uptake.

ECOLOOP - farmers support

To promote economic and social support for farmers and foresters as renewable energy prosumers through innovative and community-based solutions.

ECOLOOP - soil Living Lab

Creation of a co-innovation space through participatory and transdisciplinary systemic process related to soil health and renewable energy.

2. Methodology

In this chapter, we delve into the methodology and tools employed for gathering input on UCs, pilot site analyses, requirements, and KPIs from our project partners. The approach is segmented into three primary tasks, each with distinct objectives and processes. Under the scope of Task T2.1 "Pilot Site Analysis and Co-Creation of Project Scenarios and Use Cases," our efforts were centred around a comprehensive analysis of pilot sites. This involved a detailed examination and definition of UCs, assessing their economic, environmental, and social impacts. The task also included the iterative revision and finalization of the UCs to ensure they meet the project's goals and stakeholder expectations. Task T2.2, "Definition and Consolidation of Project Requirements," focused on the iterative process using the Volere framework to define a robust set of requirements. This task was crucial for aligning project objectives with stakeholder needs and ensuring that the developed solutions are both feasible and effective. Lastly, Task T2.3, "KPI Identification and Monitoring Preparation," was dedicated to establishing a process and defining a template for identifying KPIs. This involved designing a standardized template to define and measure the project's KPIs, facilitating effective tracking of progress and performance against the set objectives.

2.1. T2.1 Pilot Site Analysis and Co-Creation of Project Scenarios and Use Cases

Within the T2.1 Pilot site analysis and co-creation of project scenarios and UCs, we devised a five-step methodological approach to define and refine our UCs as depicted in **Figure 1**. To perform the proposed approach, project partners collaborated at various levels: at the pilot site level during ad-hoc meetings to synchronize perspectives, at the Work Package (WP) level during dedicated sessions to coordinate contributions from various pilot sites, and at the project level during bi-weekly meetings to introduce successive milestones, guiding partners towards the ultimate objective of defining the final set of ECOLOOP UCs. This progression unfolded through the following steps:

- Pilot site analysis: Drawing from the pilot site descriptions outlined in the project application, pilot sites organised dedicated meetings to examine their respective project specifics. The aim was to define the pilot site area, identify pertinent energy or other assets and shape objectives crucial for the project.
- UC definition: Leveraging insights from pilot site analysis, project partners crafted the initial roster of UCs. Regular discussions in dedicated WP and project meetings were

conducted to validate that proposed UCs aligned with the ambitious objectives of ECOLOOP.

- Economic, environmental and social impact: In this stage, the impacts were assessed at the pilot site level and discussed within WP meetings to ensure the alignment of proposed UCs with the predefined ECOLOOP Key Evaluation Results (KERs).
- UC revision: In the fourth phase, UCs underwent detailed revision using a dedicated template, assessing their innovation, necessity, technical feasibility, adherence to market principles, and ultimately deciding whether the modification was needed.
- Finalized set of UCs: The conclusive phase pinpointed UCs requiring modification, which, if required, were adjusted to guarantee their necessity, technical viability, and adherence to market standards.

Figure 1: Process of identification and finalization of ECOLOP UCs

2.1.1. Pilot Site Analysis

The pilot site analyses for each pilot were conducted using a template developed by the Slovenian pilot site, encompassing the following details:

- Description of the site.
- Description of the site's main function.
- Description of the site's main energy or other pertinent assets.
- Relevant information regarding current energy production, consumption and similar.
- Description of ECOLOOP activities.

The pilot site analyses are documented in the chapter Pilot Site Contributions and Analyses, with the dedicated subchapters for Spanish (ES) pilot, Bulgarian (BG) pilot, Estonian (EE) pilot and Slovenian (SI) pilot. The pilot site analyses should serve as an orientation for the reader to better understand the pilot site's main function and the innovations proposed in ECOLOOP.

2.1.2. Use Case Definition

The initial definitions of the UCs were established using the online tool Trello, [1]. Each pilot site contributed basic descriptions of their intended UCs and utilized labels to establish connections with the project KERs, facilitating the mapping of UCs to KERs. The KERs of the ECOLOOP project are:

- KER 1: Innovative and efficient biogas production and conversion process.
- KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process.
- KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes.
- KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater.
- KER 4: Decision support tool for farmers and foresters.
- KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols.
- KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy.
- KER 7: ECOLOOP-SOIL Living Lab.

The screenshot of the ECOLOOP Trello board can be seen in **Figure 2**. Trello aided project partners with the organization of the UCs and the tracking of the progress.
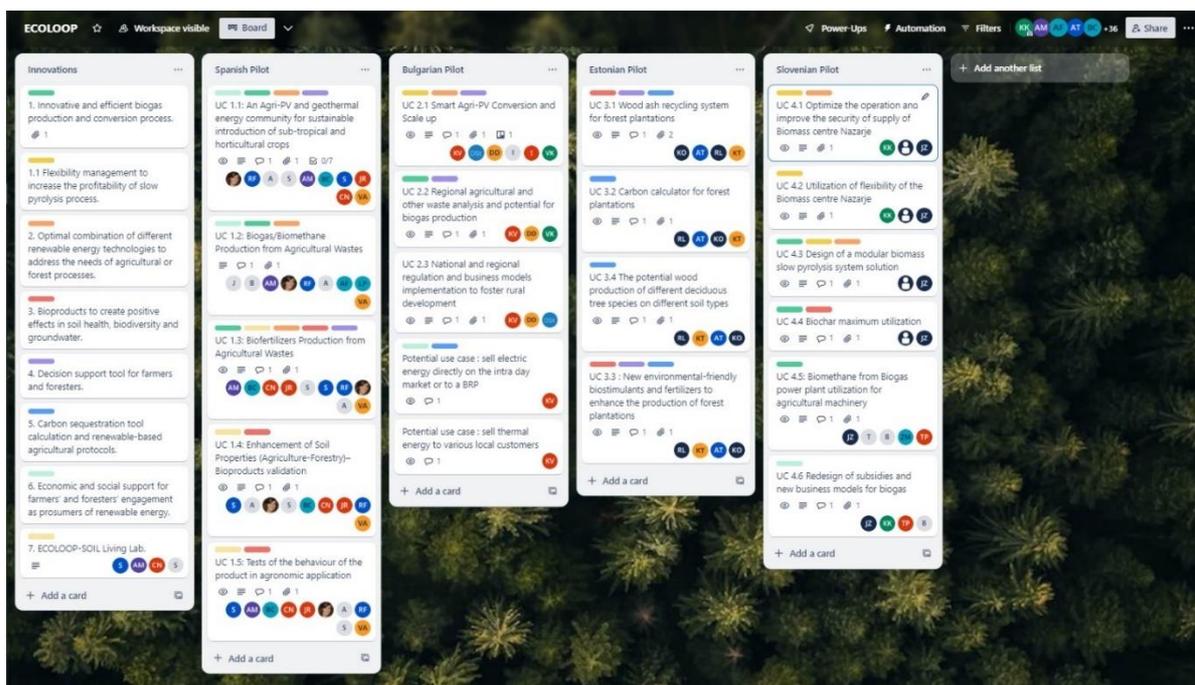
Figure 2: Screenshot from Trello

Building on the initial description of the UCs in Trello, task leader (SETUP) provided the UC template to start the detailed definition of UCs. The template included the following fields, which were filled in by the UCs leaders and contributing partners:

- UC ID: ID for UC is defined with the country code (for example, SI for Slovenia) and the serial number of the UC.
- Description: Concise description of the UC.
- Actors included: Add names of the actors involved (for example, TSO, aggregator).
- Triggering event: Describe what sets off/triggers this UC.
- Related UCs: Add any UCs that correlate in any way to the UC you are describing.
- Related ECOLOOP innovations: Add the name of ECOLOOP KERs, which are connected to the UC you are describing.
- Pre-condition: Describe the necessary conditions that should be true before the initiation of the UC for the UC execution to begin.
- Post-condition: Describe the status after the UC finalization.
- Basic paths: Describe the course of events/steps occurring sequentially (in the framework of the specific UC) under normal conditions.
- UC sequence diagram: A visual representation of the basic path sequence, which showcases the involved actors and their actions in the UC. This should be done in visually clear and readable way to make this UC easily understandable to anyone reading the document.
- Exception paths: Describe the course of events/steps occurring sequentially (in the framework of the specific UC) under abnormal conditions (alternative, error management, backup scenario). There might be none, one or more than one exception path.
- Main responsible partner: Add one or a maximum of two partners from the partner list.
- Contributing partner: Indicate all partners that should be involved in the implementation of the UC in the form of a bullet list.
- Priority: Define the priority of the UC with respect to the project. Choose from the following: low; medium; high.

The comprehensive descriptions of UCs underwent review by the contributing partners, followed by a presentation to the project consortium during a dedicated WP2 meeting. In the final phase, the task leader (SETUP) reviewed all UCs to ensure both quality and stylistic coherence. A summarized version of the UCs is catalogued in the chapter Pilot Site Contributions and Analyses, featuring dedicated subchapters for each pilot. These subchapters include concise descriptions of each UC along with their alignment with KERs. For extensive details on each UC, refer to **Annex I: Use Cases.**
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2.1.3. Economic, Environmental and Social Impact

Following the definition of the UCs, project partners started dedicated pilot site discussions to recognize the following impacts:

- Economic
- Environmental
- Social

The analyses of the impact were done with the help of a template provided by the Slovenian pilot. The idea was to provide the initial, qualitative assessment of the proposed UCs on the economic, environmental and social aspects. These topics have been further elaborated with the definition of specific KPIs. They will be monitored in subsequent WPs, with a particular emphasis in WP7, where the KPIs will be calculated and assessed. The impact assessments are documented in the chapter Pilot Site Contributions and Analyses, with the dedicated subchapters for each pilot.

2.1.4. Use Case Revision

In the UC revision phase, the template was provided by task leader (SETUP) with the following questions:

- Do you think this UC is innovative? (Y/N)
- If not innovative, do you think UC is necessary? (Y/N)
- Is the UC technically feasible? Have you identified any constraints? (Y/N)
- Is the UC in line with general market principles? (Y/N)
- What are your recommendations regarding this UC? (leave as is/modify/remove)

The questions were answered with yes or no and followed by a detailed argumentation of the proposed answer. UC leaders and contributors engaged in the dedicated meetings to elaborate on these questions and provided the final verdict of each UC – whether it should be left as it is, modified, or removed. The summary of the UC revision is documented in the chapter Pilot Site Contributions and Analyses, with dedicated subchapters for each pilot. For extensive details on each UC revision, refer to the annexes.

2.2. T2.2 Definition and Consolidation of Project Requirements

A requirement is a singular documented physical or functional need that a particular design, product, or process must be able to perform. It is a statement that identifies a necessary attribute, capability, characteristic, or quality of a system to have value and utility to a customer, organization, internal user, or other stakeholder. A requirement must be measurable and evaluable.

To achieve the objectives of the project, the requirements of the tools, products, and processes need to be clearly defined, structured and categorised. A comprehensive list of requirements defined and agreed upon by all partners is the baseline for the development of the technologies and solutions of ECOLOOP, and the foundations to build upon in subsequent technical WPs.

The goal of T2.2 was to provide a consolidated list of requirements of different types (functional, operational, legal, etc.) that encompassed the views and necessities of all partners, from field experts and technology enablers to end users and pilots. For this purpose, an iterative process based on a user-centric methodology (Volere) was used.

2.2.1. Volere Methodology

The Volere methodology [2] has been successfully used in other projects where ETRA has led the requirements definition process, such as H2020-CROSSBOW [3], H2020-TRINITY [4], and H2020-X-FLEX [5]. The methodology provides the partners with a simple way to describe, discuss, and formalize their necessities in a standardized template. The iterative nature of the methodology enables the discussion and amendment of the information until all parties agree on the final result.

2.2.1.1. Volere Tool

To facilitate the definition of requirements, the partners were provided with access to an interactive and dynamic tool, depicted in **Figure 3**. The Volere tool is a web solution based on the Volere methodology, originally developed by ETRA and used with success in different projects such as the aforementioned ones. For security reasons, access to the tool is restricted to authorized users.
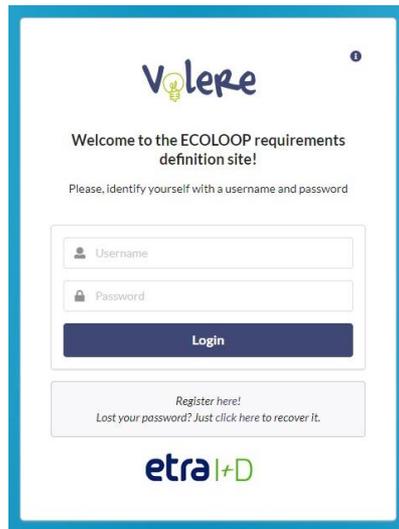
Figure 3: Access form to the Volere tool

The tool allows the administrator to manage the status of the requirements definition process as defined by Volere, moving from stage to stage until the final list is complete.

2.2.1.2. Specification Process

The iterative process of specification and validation of requirements in Volere is depicted in **Figure 4.**
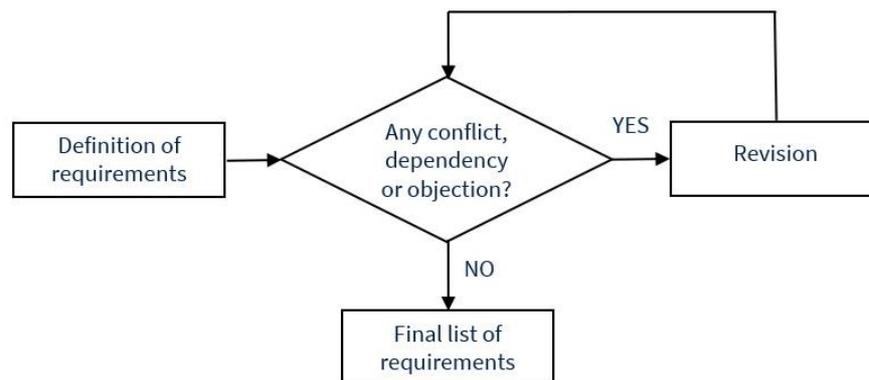
Figure 4: Specification and validation of requirements in Volere

A preliminary list of requirements is initially defined by all partners involved. A set of iterative cycles is then scheduled, where partners first try to identify issues or propose modifications to the requirements (validation phase), which are subsequently addressed by the original authors (revision phase). This, together with any new requirements added during the

iteration, results in a new list of requirements, which is subject to the same process until no more modifications are identified. A scheme of this process is shown in **Figure 5.**
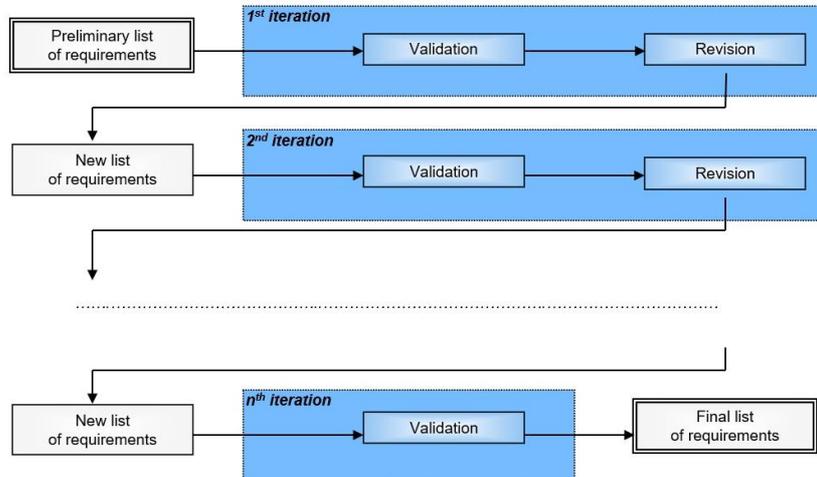
Figure 5: Iteration cycles in Volere methodology

Each iteration and stage inside are scheduled for a specific time frame to keep the process advancing. The different stages of the process are further explained in subsequent sections.

2.2.1.3. Requirements Definition

The Volere tool provides a graphical user interface (GUI), to define and keep track of the list of requirements.

Figure 6: Volere tool GUI

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The following functionalities are shown on the main page of the Volere tool, as shown in **Figure 6**:

- **Stage tracking:** A breadcrumb trail is shown at the top of the page to identify the current stage of the definition process and all previously completed stages, in order.
- **Requirements list:** A table with the list of requirements being considered in the current stage of the process. It shows a summary of the template fields with filtering options and the possibility of expanding the information to all fields. Controls for editing and deleting the requirements created by the user are available as well during the revision phase.
- **Show requirements history:** After the first validation process, a separate page can be accessed showing the whole history of the requirements, including modifications, identified issues, comments from partners, and deletions.
- **Export to a comma-separated value (CSV) file:** The tool allows the exporting of the current list of requirements (including new ones) as a CSV file.
- **Dependencies, conflicts, and objections:** List of open issues identified by the partners in the validation process of the current iteration. Revisors can add comments to further explain or justify the suggested modifications.
- **New requirements list:** Includes new requirements added during the current iteration, which will be incorporated into the full list of requirements in the next iteration for their validation.
- **Insert a new requirement:** Template to add new requirements at any step of the process. It opens in a new window and includes the following fields:
- **Requirement ID:** An automatically generated sequential identifier, added once the requirement is inserted. The format of the ID includes the abbreviation of the classification of the requirement, followed by an underscore ("_"), and a sequential 3-digit number. The identifier is unique, and will not be re-used if the requirement is deleted.
- **Classification:** High-level category of the requirement. In ECOLOOP, the classification of the requirements was based on each of the 8 KERs, with an additional category for general requirements (which was eventually unused.)
- **Description:** Direct and concise definition of the requirement in one sentence, expected to follow the syntax "[Trigger] [Precondition] Actor Action [Object]" (e.g. "When an order is shipped and order terms are not prepaid, the system shall create an invoice.") In ECOLOOP, it was also agreed to prefix the description with the UC(s) the requirement applied to, or "[Global]" for general requirements.
- **Type:** Typification of the requirement as defined by Volere [2].
- **Priority:** Urgency in the fulfilment of the requirement, from 1 (lowest priority, accessory) to 5 (highest priority, essential).

- **Rationale:** Motivation behind the requirement, reason(s) why it is relevant for the project.
- **Acceptance criteria:** Condition to mark the requirement as fulfilled by the implementation once it is evaluated.
- **Comments:** Additional comments or details to further understand the requirement.

The new requirement form is depicted in **Figure 7**, while the example of a completed form is depicted in **Figure 8**.

Figure 7: New requirement form

Project requirement detail on 6th iteration

Id.	K11_004
Classification	Flexibility management to increase the profitability of slow pyrolysis
Description	[UC 4.1, UC 4.2] The aggregator platform shall collect data from flexibility assets.
Type	Functional requirements - Functional and data requirements
Author	SETUP (Klemen Kosovinc)
Date	24/05/2024
Rationale	The aggregator has to collect the measurement data of the assets to successfully perform the ancillary services and technical and economic optimization calculation.
Acceptance criteria	Data is collected in time interval <= 15 minutes.
Priority	★ ★ ★ ★ ★
Comments	

Close

Figure 8: Example of requirement template

2.2.1.4. Requirements Validation

Once the preliminary list of requirements is ready, the validation process starts. All partners are required to review the list trying to identify three types of issues:

1. **Dependency:** Requirements whose fulfilment depends on the partial or total implementation of other requirements.
2. **Conflict:** Requirements that cannot be implemented if another requirement is implemented, or a conflict due to an insufficient definition of a requirement.
3. **Objection:** A reason or argument offered in disagreement, opposition, refusal, or disapproval of the requirement.

The issues are shown in their corresponding table according to their type, as explained in the previous section. One issue can involve one or more requirements.

2.2.1.5. Requirements Revision

All dependencies, conflicts, and objections created during the validation stage must be revised and solved by the authors of the involved requirements. If they agree with the proposed changes, they can proceed to modify the original requirement, delete it, create new ones, or any other action expected. If they disagree, they can include a comment for the validator (creator of the issue) to justify why the modifications will not be performed.

Both the validator and the revisor(s) must check the corresponding checkboxes associated to the issue for the process to be considered as complete. The evolution of a requirement can be accessed in the tool, as shown in **Figure 9.**

Figure 9: Example of the evolution of a requirement

2.3. T2.3 KPI Identification and Monitoring Preparation

This subchapter explains the approach taken to identify KPIs for ECOLOOP. **Section 2.3.1** describes the process used by the ECOLOOP partners to develop these KPIs. **Section 2.3.2** focuses on the common template that was created for defining the KPIs. The output of this task will be the basis to elaborate the final evaluation and impact assessment plan in WP7, where the developed methodology will be further tailored within the context of each pilot site where local characteristics and applied BMs will be considered.

2.3.1. Identification of KPIs

In the case of ECOLOOP, KPIs have been divided into two groups: project KPIs and demo-specific KPIs.

ECOLOOP's demonstrations focused on four pilot sites, which are reflected in the project KPIs and support evaluation of the wide range of solutions' performance proposed by pilot sites in reaching the project goals. As a first step to define the KPIs, the project's objectives were analysed. The project aims to:

- **Promote the penetration of decentralized renewable sources** in the energy system of agriculture and forestry sectors, improving cost-effectiveness, sustainability, and circularity of energy demand.
- **Optimize agricultural and forest waste management** to reduce associated emissions.
- **Enhance soil properties, biodiversity, and groundwater conditions** through advanced bioproducts.
- **Foster regional development in rural areas**, empowering farmers and foresters with innovative BMs, financial instruments, and policy recommendations.

To achieve these objectives, KPIs from the Grant Agreement were analysed and categorized by UC and KER. The KPIs were further divided into technical, social, environmental, and economic domains. These categories allow for the classification of KPIs into groups that monitor similar functions, facilitating the filtering and identification of KPIs relevant to the reader.

The next step involves identifying pilot-specific KPIs, as each pilot site employs different technologies or approaches to achieve the objectives. Identifying these specific KPIs is crucial in the KPI definition process.

Finally, once the ES, BG, EE, and SI pilots have identified their initial pilot-specific KPIs, each pilot evaluates the KPIs proposed by the other pilots to determine which KPIs can be shared across multiple pilots. This task enables valuable comparisons, simplifies the extensive list of KPIs, and identifies commonalities among the different pilot sites. With this information, the KPI mapping will be completed, and it will be clear which KPIs are covered by each pilot.

2.3.2. Definition of KPIs

For the task of defining KPIs, a template was created for both project- and pilot-specific KPIs. This template, included in the **Annex III: Requirements**, is organized into two main sections: Basic KPI Information and KPI Calculation. The details of these sections are outlined below.

1. **Basic KPI Information** - General KPI Information:
   - **KPI ID** - KPI Identification number. ID for KPI is defined with the country code (for example, ES for SPAIN and the serial number of the KPI, or KPI and the GA for the KPI from the Grant agreement and the serial number).
   - **KPI name** - Name of KPI, clearly explaining what the indicator intends to measure.
   - **Strategic objective(s)** – ECOLOOP's main objectives KPI is covering.
   - **Related ECOLOOP innovation** – ECOLOOP innovation related to the KPI.
   - **Related UC** – UC related to the KPI.
   - **Responsible** - Person and/or company responsible and accountable for a single KPI.
   - **KPI description -** Description of KPI further clarifying what the indicator intends to measure.
   - **KPI formula** - Precise mathematical formula for calculating KPI, and explanation of defined formula.
   - **Variables explanation -** Explanation of the variables in the KPI formula.
   - **Unit of measurement** – E.g. percentage basis, MW, MWh, etc.
   - **Baseline –** Description of the chosen baseline.
   - **Target/thresholds** - The target of KPI relative to the defined baseline.

Other comments – A short explanation of how the KPI will be evaluated. **2. KPI Calculation Methodology** – Methodology for calculating KPI, listed step-by-step:

   - **KPI calculation step ID** – Calculation step identification number.
   - **Step** – Description of steps taken during the calculation of KPI.
   - **Responsible** – Person and/or company responsible for specific steps in KPI calculation methodology

3. Pilot Site Contributions and Analyses

In this chapter, we present a comprehensive analysis of the pilot sites, offering a thorough summary of UCs, alongside an in-depth assessment of their economic, environmental, and social impacts. Additionally, we compile a detailed summary of the revisions made to these UCs based on the findings from all pilot sites. The chapter is structured to serve as an initial overview of all pilot activities within the ECOLOOP project, setting the stage for understanding the broader scope and objectives of our initiatives. Detailed descriptions of each UC and the UC revisions are collected in

Annex I: Use Cases and **Annex II: Use Cases Revision.**

3.1. ES Pilot Site

3.1.1. Pilot Site Analysis

The Spanish pilot site is primarily located in the **L'Horta Sud** district of **Valencia** and its surroundings. L'Horta Sud is known for its rich agricultural heritage, producing a variety of crops such as citrus fruits, vegetables, and ornamental plants. This district combines traditional farming practices with innovative approaches to sustainable agriculture and energy production, making it an ideal location for implementing and testing renewable energy solutions within agricultural settings. As a result, L'Horta Sud was selected as the location to establish a sustainable energy community model, with key components including:

- **Agri-PV system:** Combining agriculture with PV technology to support sub-tropical, vineyard, and horticultural crops.
- **Geothermal energy:** Utilizing heat from the subsoil to provide heating, air conditioning, and hot water for Agri-PV structures, mushroom cultivation, and fruit storage chambers or refrigerators.

The Energy community of L'Horta Sud, depicted in **Figure 10**, aims to hybridize **Agri-PV and geothermal energy**. Solar panels will generate energy to power a heat pump, extracting heat from the subsoil for various applications. This technological combination is expected to enhance crop production by stabilizing temperatures and preventing adverse effects on crops. Currently, the infrastructure at the pilot site includes 120 m² of bifacial PV technology, with a theoretical energy generation capacity of 105 MWh per year. These panels are installed on the ground and on the rooftops of existing buildings at the site.

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In addition to the PV project, a **biogas plant pilot** will be established in the Horta Sud area of Valencia, likely in the **town of Beniparrell**, on an approximately 800 m^2 site. The biogas plant will include an **anaerobic digester** (AD) to process local **agricultural biowaste**. It is estimated that the plant will process about **5 to 6 tons of waste per day**, comprising 4 to 5 tons per day of fruit and vegetable waste. With these inputs, the pilot is expected to produce **7 to 8 Nm³ of biogas per hour**. The design, development and validation of an innovative process to upgrade produced biogas to vehicle-grade biomethane, will be **validated in a laboratory-scale pilot plant** to ensure the use of the biomethane produced for sustainable transport in the region. This small-scale and laboratory pilot plant for biomethane production will be developed in **T3.1 "Innovative and efficient biogas production and conversion",** which will be based on a **hydrophobic membrane technology**. This membrane offers a modular solution for biogas upgrading, adaptable to a wide range of biogas fluxes and especially appealing for **anaerobic digestion facilities in rural areas**. The AD design will include the following steps: characterizing agricultural residues, designing the AD and its pre-treatment processes, designing the biogas unit treatment and auxiliary systems, and developing the process control system.

Figure 10: Spanish pilot site

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In addition, the **biofertilizers** produced from the biogas digestate, are going to be tested, among others, in **"Finca Sinyent",** an essay farm owned by **AVA-ASAJA, located in Polinya del Xuquer**, a small town 30 km down to Valencia. The farm itself, currently covers 30 hectares, including infrastructure and crops, which have been designed in plots of approximately 1 hectare, for the experimental and essay's sake. Finca Sinyent has a primary **irrigation network installed**, which consists of 6 hydraulic lines to be able to alternate different fertilizers and applications. For this purpose, it has an advanced **remote-control system** that allows to maximize of the control possibilities of the different parameters of each plot.

Furthermore, each plot is subdivided into four irrigation units, a condition that facilitates experimentation with different parameters.

Likewise, there is an agricultural warehouse of approximately 1,000 m^2 with the appropriate machinery, cold rooms, a testing laboratory, a warehouse for phytosanitary products, and crop handling machinery, among others. These facilities are designed exclusively to handle **essays and experimental testing**.

The farm also has an **Agroclimatic Information System for Irrigation (SIAR)** installed in the farm, which provides official climatological data so that farmers and agricultural technicians have the information they need to calculate crop irrigation requirements and improve water use efficiency.

To test the effectiveness of the bioproducts produced in WP6, two plots have been allocated within the farm´s area. The crops chosen for the testing are horticulture and khaki (Persimmon).

In addition to forest, subtropical and citrus, the effects of biofertilizers can therefore be monitored in several crops. The results will help to provide a more complete picture of biofertilizers.

3.1.2. Use Cases

Spanish partners within ECOLOOP will address the UCs presented in **Table 1.**

Table 1: ES pilot site UCs

UC ID	Name
UC ES.01	An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops

UC ES.02	Biogas/biomethane production from agricultural wastes
UC ES.03	Biofertilizer production from agricultural wastes
UC ES.04	Enhancement of soil properties (agriculture-forestry) bioproducts validation
UC ES.05	Tests of the behaviour of the product in agronomic application

UC ES.01 will develop a 1.5 MW Agri-PV and integrate greenhouses with geothermal and biogas systems. Featuring 320 m² of bifacial PV panels, the site will generate 105 MWh annually, providing power for heating and cooling for greenhouses, mushroom cultivation, and refrigeration.

UC ES.02 features a compact biogas plant tailored to process agricultural waste from crops using an AD. This includes comprehensive design aspects such as waste characterization, pre-treatment, biogas unit treatment, auxiliary systems, and process control systems.

Furthermore, **UC ES.03** involves a biogas plant treating organic waste to produce both biogas and digestates. As part of the project, a nutrient recovery system will be installed to produce biofertilizers from the organic digestates, enhancing their nutrient value. Soil improvers will also be generated for forestry applications, contributing to sustainable land management.

UC ES.04 will tackle two main challenges of the Spanish pilot: revitalizing agriculture and enhancing soil quality. This involves evaluating a new bioproduct from local agricultural residues to boost productivity in degraded soils and aligning conventional farming with circular and green agriculture principles. The goal is to improve soil indicators like organic matter and physical properties in agricultural and forestry plots.

UC ES.05 validates the benefits of returning harvest debris to fields and assesses improved digestate formulations through sprouting tests. It aims to optimize agronomic management for different formulations, focusing on improving agronomic parameters. Trials employ statistically robust designs to comprehensively evaluate treatment efficacy.

The contribution of the Spanish UCs to the ECOLOOP KERs can be seen in **Table 2.** The Spanish pilot contributes to 6 KERs: KER 1 "Innovative and efficient biogas production and conversion process", KER 2 "Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes", KER 3 "Bioproducts to create positive effects on soil health, biodiversity and groundwater", KER 4 "Decision support tool for farmers and foresters", KER 6 "Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy" and KER 7 "ECOLOOP-soil Living Lab".

Table 2: ES pilot site UC-KER mapping

	UC ES.01	UC ES.02	UC ES.03	UC ES.04	UC ES.05
KER 1		■	■		
KER 1.1					
KER 2	■	■	■		
KER 3			■	■	■
KER 4	■	■	■		
KER 5					
KER 6	■				
KER 7			■	■	■

3.1.1. Economic, Environmental and Social Impact

The implementation of the described UCs will result in the following impacts on the environment, economy and social acceptance:

Environmental Impact
- **UC ES.01** will help the realisation of sustainable energy practices, such as the closed loop system for temperature control of the greenhouse and mushroom houses, reducing energy waste, conserving water and optimising resource use. Also, by using PV energy for temperature control, it will avoid dependence on electricity produced from fossil fuels and reduce the environmental impact.

- **UC ES.02** and **ES.03** will contribute to waste management by converting agricultural residues into valuable biogas and biofertilizers.

- **UC ES.04** will enhance soil quality through the validation of bioproducts, benefiting agricultural and forestry practices.

- **UC ES.05** will ensure that agronomic applications of products are environmentally sustainable.

Social Acceptance
- **UC ES.01** will help in the adoption of a renewable energy community model that may attract the attention of other residents or farmers interested in a more sustainable and off-grid way of farming. Also, it will help to visualise that it is possible to obtain the energy needed for such installations from renewable sources.

- **UC ES.02** will provide opportunities for farmers to manage agricultural waste effectively while producing valuable resources.

- **UC ES.03** will provide new bioproducts using digestate from biogas production, avoiding its contamination.

- **UC ES.04** will validate bioproducts for soil enhancement, earning trust and acceptance from agricultural and forestry communities.

- **UC ES.05** will ensure that agronomic practices are socially acceptable and aligned with sustainability goals.

Economic Impact

- **UC ES.01** will assist in the cultivation of subtropical crops and mushrooms, which previously was not possible or the cost of making it possible was too high due to energy consumption. It will create an opportunity to exploit different varieties of crops that have not been previously explored and with greater profit. In addition, the non-dependence on the electricity grid due to the energy produced by the PV panels will lead to economic savings.

- **UC ES.02** will generate additional revenue streams for farmers through the production of biogas.

- **UC ES.03** will generate additional revenue streams for farmers through the production of biofertilizers from digestate generated in the biogas production.

- **UC ES.04** will enhance agricultural productivity, leading to economic gains for farmers and foresters.

- **UC ES.05** will ensure that agronomic applications are economically viable and contribute to long-term sustainability.

3.1.2. Use Case Revision

Table 3 provides an overview of the UC revision of the Spanish pilot site. **UC ES.01** is the only Spanish UC not marked as innovative, but still important for the scope of the project as it integrates Agri-PV and geothermal energy for cultivating subtropical crops and mushrooms, which is, in normal circumstances, not economically viable. The other four UCs are marked as innovative, as they are proposing innovation in the fields of **producing biomethane, using waste for biogas plants**, enhancing the quality of soil using bioproducts and enhancing the quality of crops using bioproducts – all the above have not been done before or not for similar purposes.

Table 3: Spanish UCs revision overview

UC ID	UC innovative?	If not innovative, UC necessary?
UC ES.01	No	To create a conducive context for cultivating economically viable subtropical crops and mushrooms, it's imperative to integrate Agri-PV and geothermal energy. This combination not only fulfils the energy requirements of these crops but also enables optimization of energy consumption. Additionally, synergizing the energy generated by the biogas plant with Agri-PV and geothermal sources further enhances overall efficiency and sustainability.
UC ES.02	Yes	/
UC ES.03	Yes	/
UC ES.04	Yes	/
UC ES.05	Yes	/

3.2. BG Pilot Site

3.2.1. Pilot Site Analysis

ALBENA is located in the Dobrich region, **Balchik Municipality**. It is the largest tourist company in **Bulgaria** and its resort is located on the **northern Black Sea coast** in a district, which itself is the top cultivated region in the country. The size of the area is 4,720 km^2, and **81 %** of all the land in **Dobrich region is agricultural**. The major crops grown are wheat, barley, sunflower, rape and corn. Bulgaria is the world's largest producer and exporter of lavender, lavender oil and rose oil. ALBENA aims to continue its development with a direction towards the **local circular economy** within the company and its subsidiaries which are active in different sectors such as agriculture, bioenergy, real estate, tour-operating, medical services, transportation, construction and others.

The Bulgarian pilot site, depicted in **Figure 11**, is located in the **Momchil area** near the town of Balchik (also part of the Dobrich region). **Two main initiatives** are being developed, working synergistically to create a sustainable business model through the combination of different RES.

Figure 11: Bulgarian pilot site in Momchil area near Balchik

The first initiative is related to agricultural endeavours. In the frame of the ECOLOOP project, ALBENA is focused on the **integration of PV technology** to convert existing greenhouses into **smart greenhouses with remote thermal regulation**, aimed at increasing yield cycles and reducing carbon emissions in agricultural production. The PV system will be installed to achieve complete **self-sufficiency level** of the necessary electricity for the long-term development of the pilot site – in the future, it is expected that the construction will include but will not be limited to new greenhouses, mushroom farms and cowsheds. In combination with thermal energy produced by the existing biogas plant channelled properly by pipes, the optimal temperatures required for the smart greenhouses will be automatically controlled, thereby **raising the annual yield cycles while also reducing costs and CO_2 emissions**.

The second initiative is related to the site's **biogas facility** (depicted in **Figure 12**), which plays a critical role in this sustainable ecosystem. The biogas facility processes approximately 2,200 tons of food waste, 1,000 tons of manure, and 12,000 tons of corn silage annually, to **produce approximately 6,500 MWh of electricity and 520 MWh of thermal energy**. The thermal energy is used as a tool for regulating optimal temperatures in the greenhouses. The biogas facility not only **supports the site's energy needs** but also **contributes to a circular economy model**, reducing waste and enhancing soil quality through the application of biogas byproducts.

In a collaborative effort with TRU, ALBENA is undertaking a comprehensive analysis of agricultural and organic waste to assess its biogas production potential. This endeavour aims to refine the use of various waste types, moving away from the heavy reliance on corn silage towards a **more sustainable model** utilizing a larger amount of **agricultural waste** and

potentially exploring other options such as growing plants that provide high potential for biogas production and have not been used in Bulgaria before.

Figure 12: Biogas facility processes corn silage

3.2.2. Use Cases

Bulgarian partners within ECOLOOP will address the UCs presented in **Table 4.**

Table 4: BG pilot site UCs

UC ID	Name
UC BG.01	Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes
UC BG.02	Regional agricultural and other waste analysis and potential biogas production
UC BG.03	National and regional regulation and business model's implementation to foster rural development

In **UC BG.01**, ALBENA will enhance its greenhouses with photovoltaics and integrate thermal energy from the existing biogas plant to create smart greenhouses. This transformation aims to optimize yield cycles and minimize CO_2 emissions in agricultural production.

In the scope of **UC BG.02**, ALBENA and TRU will research local agricultural and organic waste for biogas potential, testing samples in the pilot site's biogas plant. They'll evaluate the waste impact on biogas production and biogas byproduct fertilizer's impact on soil, explore biogas storage, and provide data for a decision support tool, developed in WP4, for predictive biogas analysis.

The **UC BG.03** boosts renewable energy in local agriculture by analysing regulations, economics, and social factors. It identifies suitable technologies, fosters cooperatives, and collaborates with policymakers for favourable conditions.

The contribution of the Bulgarian UCs to the ECOLOOP KERs can be seen in **Table 5**. The Bulgarian pilot will work on KER 1 "Innovative and efficient biogas production and conversion process", KER 2 "Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes", KER 4 "Decision support tool for farmers and foresters" and KER 6" Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy".

Table 5: BG pilot site UC-KER mapping

	UC BG.01	UC BG.02	UC BG.03
KER 1		■	
KER 1.1			
KER 2	■		
KER 3			
KER 4	■	■	
KER 5			
KER 6			■
KER 7			

3.2.3. Economic, Environmental and Social Impact

The implementation of the described UCs will result in the following impacts on the environment, economy and social acceptance:

Environmental impact

- **UC BG.01** will promote sustainable energy practices in agriculture, reducing carbon footprint by integrating RES.

- **UC BG.02** will contribute to waste management by converting agricultural residues into valuable biogas and biofertilizers and will contribute to soil improvement when byproducts are used as fertiliser.

- **UC BG.03** will help farming communities in Bulgaria adopt RES like wind, solar, biogas, and biomass, which will significantly reduce greenhouse gas emissions associated with conventional energy sources. Transitioning to cleaner energy sources helps in reducing pollution and habitat destruction.

<u>Social acceptance</u>

- **UC BG.01** will foster the development of energy communities focused on sustainable crop production, garnering support from local stakeholders.

- **UC BG.02** will provide opportunities for farmers to manage agricultural waste effectively while producing valuable resources (biogas and bioenergy).

- **UC BG.03** will help the rural agriculture communities sense of "empowerment" by encouraging cooperative models fostering a sense of ownership and empowerment among community members, as they collaboratively invest in and benefit from renewable energy. Access to reliable and clean energy can improve living conditions, supporting local industries and enabling the development of community facilities.

<u>Economic impact</u>

- **UC BG.01** will create economic opportunities through the establishment of energy communities, supporting sustainable agricultural practices. Investing in PV will lead to long-term financial benefits from reducing costs of electricity as well as the potential for increased agricultural yield, enhancing profitability.

- **UC BG.02** will provide the necessary information for the development of additional revenue streams and beneficial operational models for the functioning of the biogas facility, as well as inventing optimal mixtures of the proper materials such as agri/food waste, plants, manure, silage and similar.

- **UC BG.03** will have a positive impact on employment opportunities - developing and maintaining renewable energy systems can create new jobs within the community, from construction to ongoing operational roles. By generating their energy, communities can reduce their vulnerability to fluctuating energy prices and supply disruptions.

3.2.4. Use Case Revision

Table 6 provides an overview of the UC revision of the Bulgarian pilot site. **UC BG.01** offers both innovation and familiarity, leveraging proven methods while introducing fresh

perspectives like integrating multiple renewable sources with smart monitoring and enriching the Bulgarian pilot with diverse approaches. **UC BG.02** stands out for its innovation, centring on biogas production from organic waste and the creation of a digital tool for predicting production and soil fertilization effects. The innovation of **UC BG.03** lies in the use of a people-centric approach for establishing local agro-energy communities in Bulgaria.

Table 6: Bulgarian UCs revision overview

UC ID	UC innovative?	If not innovative, UC necessary?
UC BG.01	Yes	/
UC BG.02	Yes	/
UC BG.03	Yes	/

3.3. EE Pilot Site

3.3.1. Pilot Site Analysis

Estonia is located in a boreal climate zone with a forest cover of about 50% of the total area. The share of **woody biomass** (low-quality timber, cutting and wood industry wastes) from renewable energy production is currently about **25%**. Woody biomass as a bioenergy source is especially important in regional heating systems. The Estonian pilot area consists of a **network of pilot sites of short-rotation forestry plantations and a biorefinery pilot** for biomaterials production. The network of pilot sites consists of **70 individual sites** that cover different soil types, forest management practices and fertilization, as depicted in **Figure 13**.

The pilot sites cover various deciduous tree species such as hybrid aspen, silver birch and black alder, that are considered suitable for future biorefineries and the carbon credit market. In addition, these species can **improve resilience to climate change** by replacing climate-sensitive spruce monocultures and reducing overall cutting pressure on native forests. Plantations are established on abandoned agricultural lands. The results from the different pilot sites will be implemented in the general Estonian area by considering the available land area and soil type classification.

The pilot sites will provide the input data, such as growth and soil quality, for the state-of-art growth and yield models. Novel growth and yield models will be the input data for **the carbon calculator tool** - an open-access web platform to estimate the climate benefits such as sequestrated carbon and substitution, carbon credit, financial profit and similar.

Figure 13: Estonian pilot site ecosystem

FIBE flagship biorefinery in Imavere (Estonia), depicted in **Figure 14**, valorises more than **90% of wood residues** into novel biomaterials such as lignin, wood sugars and special cellulose with unique Sunburst technology. The pilot plantations will be the basis for the analysis of the potential of biomass utilization as a **renewable source to produce woody renewable biomaterials**. It will involve the testing of, at least, **three new wood species**, grown in various soil types, that will take place at the biorefinery in Imavere, previously mentioned.

ECOLOOP demonstration activities will allow in-depth analyses of how the wood composition from novel fast-growing short-rotation forest plantations in Estonia will affect the properties of new high-value low-carbon biomaterials such as lignin, wood sugars and special cellulose and its production with **minimal environmental impact**. The produced biomaterials will **replace fossil-based sources** in various industry fields such as storage systems, biochemicals, bio-based plastics, construction materials, packages, cosmetics, and pharmaceuticals. The residue used as feedstock is wood residue – second-generation biomass from forestry or wood processing industries that originate only from certified and sustainably managed forests. FIBE will contribute to the resourceful and energy-efficient cascading use of sustainably sourced biomass.

Figure 14: FIBE flagship biorefinery in Imavere

3.3.2. Use Cases

Estonian partners within ECOLOOP will address the UCs presented in **Table 7.**

Table 7: EE pilot site UCs

UC ID	Name
UC EE.01	Wood ash recycling system for forest plantations
UC EE.02	Carbon calculator for forest plantations
UC EE.03	New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations
UC EE.04	The potential wood production of different deciduous tree species on different soil types

The main aim of the **UC EE.01** is to utilize nutrient-rich wood ash to enhance tree growth. Wood ash, a byproduct of heating systems utilizing woody biomass for energy production, contains a range of macro and micronutrients beneficial for supporting tree growth. By

examining the pilot site where wood ash fertilization will be implemented, this initiative seeks to develop effective methods for reintegrating wood ash into forest plantations.

UC EE.02 aims to create a carbon sequestration calculator tailored for forest plantations using data from the pilot site. The calculator will estimate CO_2 sequestration, the potential profit from CO_2 credits, and climate benefits from the substitution effect by accommodating variables like tree species and soil type. Accessible as a free web platform, it will aid private landowners, forest companies, decision-makers, and non-government organizations in assessing the impact of CO_2 sequestration.

Furthermore, **UC EE.03** investigates *"arGrow"*, a new biostimulant, and mineral fertilizers' impact on deciduous forest growth to develop certification systems for legalizing fertilization in forests, aiming to enhance production sustainably.

The last UC, **UC EE.04** will examine the potential of Estonian forest plantations across diverse soils for a full rotation cycle. Monitoring 70 pilot sites and modelling their yield on different soils will inform afforestation scenarios, assessing maximum, medium, and minimum potential areas for woody biomass production.

The contribution of the described UCs to the ECOLOOP KERs can be seen in **Table 8**. The Estonian pilot will be focusing on KER 3 "Bioproducts to create positive effects on soil health, biodiversity and groundwater", KER 4 "Decision support tool for farmers and foresters" and especially on KER 5 "Carbon sequestration tool calculation and renewable-based agricultural protocols".

Table 8: EE pilot site UC-KER mapping

	UC EE.01	UC EE.02	UC EE.03	UC EE.04
KER 1				
KER 1.1				
KER 2				
KER 3	▓			▓
KER 4	▓			▓
KER 5	▓	▓	▓	
KER 6				
KER 7				

3.3.3. Economic, Environmental and Social Impact

The implementation of the described UCs will result in the following impacts on the environment, economy and social acceptance:

<u>Environmental impact</u>

- **UC EE.01** on the nutrient-rich wood ash recycling will stimulate the deciduous trees plantations' productivity and carbon sequestration on organic soils, reducing greenhouse gas emissions from abandoned peatlands.
- **UC EE.02** based on the development of the carbon calculator tool will estimate the climate mitigation effect through carbon uptake and the amount of CO_2 fixed in forest plantations.
- The modelled production values from the pilot sites obtained in **UC EE.04** will allow the comparison of the potential ecological consequences of afforestation of former agricultural lands with different tree species on various soil types in Estonia.
- **Valorising residues and low-quality wood** from the plantations, forestry and wood processing industry (FIBE) as feedstock in their process contributes to resource efficiency and supports a circular bioeconomy.
- **Reduced greenhouse gas emissions** by substituting fossil-based materials and energy sources with wood and biomaterials.

<u>Social acceptance</u>

- **All Estonian UCs** are poised to foster the creation of new jobs with high added value, thus collecting positive approval from diverse communities, including the foresters and farming community.
- The modern industrial-level practices, development and production of novel sustainable biomaterials will boost innovation and create jobs in rural areas.

<u>Economic feasibility</u>

- **Novel BMs** about forest plantations integration to the industry-based approaches to develop and produce novel renewable biomaterials for the implementation of the circular bioeconomy.
- **The carbon calculator** estimates the potential profit from CO_2 credit and estimates the climate benefit from the substitution effect, i.e. avoided CO_2 release from fossil energy and materials.
- **The legalized fertilization** of forest plantations is a sustainable approach to producing more renewables in the region and creating new jobs in rural areas.

3.3.4. Use Case Revision

Table 9 provides an overview of the UCs revision of the Estonian pilot site. Two UCs, **UC EE.02** and **UC EE.03**, stand out for their innovation as they explore or pioneer new fields, carbon calculator for forest plantations and new environmental-friendly fertilizers to enhance the production of forest plantations, while the remaining two, **UC EE.01** and **UC EE.04**, although not deemed innovative, offer significant value to the project by filling gaps in areas such as wood ash recycling wood production of different tree species on different soil types, that are currently less explored as explained in the table.

Table 9: Estonian UC revision overview

UC ID	UC innovative?	If not innovative, UC necessary?
UC EE.01	No	At the moment, there are only a few fragmentary baseline results from small experimental forest plantations in Estonian conditions. The first results from deciduous tree species plantations describing potential production are very promising.
UC EE.02	Yes	/
UC EE.03	Yes	/
UC EE.04	No	The UC provides new information about specific tree species (birches, aspens, alders) wood production on abandoned agricultural lands, while the previous data comes mostly from forestland stands or does not cover the whole rotation cycle in plantations.

3.4. SI Pilot Site

3.4.1. Pilot Site Analysis

The Slovenian pilot site comprises **two locations**, the first one found in **the Biomass Centre Nazarje**, which is located within an **industrial zone**. The primary function of the Biomass Centre Nazarje is the **processing of wood waste**, including waste from wood industries and sawmilling, into woody biomass (**Figure 15**). This processed biomass serves as a valuable resource for **generating power and heat**, as well as for the production of **wood fuels**. The comprehensive production process, encompassing processing, preparation, transport, and the feeding of materials into the wood gasifiers (integral components of the biomass power plant) is **fully automated and monitored in real-time** through a dedicated **central control system.** The biomass power plant operation is based on the **pyrolysis process** and consists of a **wood gasifier and a Combined Heat and Power (CHP) system**. The wood gasifier efficiently utilizes both wood chips and pellets to produce a combustible gas, known as **"wood gas"**, which is then directed into the CHP system to generate both heat and power.

The existing infrastructure consists of **12 modular CHP units**, collectively providing a total power output of **550 kW$_e$ and 1,200 kW$_{th}$**. Additionally, there is a wood chips boiler with a **capacity of 4,900 kW$_{th}$** and a facility for woody biomass storage.

The present annual wood fuel production encompasses around 150,000 nm^3 of naturally dried wood chips, 25,000 nm^3 of technically dried wood chips, 15,000 tons of pellets, and 500 tons of briquettes. The **electricity generated** from woody biomass is approximately **6.5 GWh**, while **thermal energy production** is around **10 GWh**.

Biomasa is poised for strategic investments in its infrastructure, including a CHP unit with a capacity of 500 kW$_e$, another CHP unit with a capacity of 300 kW$_e$, two wood chips boilers with a combined thermal power of 5,500 kW$_{th}$, the establishment of a new wood chip storage facility, installation of EV charging station(s), deployment of a PV power plant, and integration of a battery energy storage system (BESS).

Figure 15: Slovenian pilot site Nazarje

The second pilot location, located at **the IC Jablje (Infrastructure Center Jablje) owned by the Agricultural Institute of Slovenia (KIS),** features a modular **micro biogas plant**. KIS has installed this plant, which is set to undergo upgrades including the addition of a biomethane production unit—comprising biogas cleaning and upgrading to biomethane—as well as a biomethane filling station for refuelling tractors converted to run on biomethane.

The micro biogas plant, depicted in **Figure 16**, includes an anaerobic digestor (AD) with a **capacity of 24 m³** and a biogas holder capable of storing **18 m³ of biogas**. Additionally, it features a **biogas cogeneration unit** with a power output of **7 kW$_e$ and 16 kW$_{th}$**. The biomethane produced will be stored and utilized as an **environmentally friendly fuel** for agricultural machinery as tractors, in the case of the project.

Figure 16: Modular micro biogas power plant IC Jablje

3.4.2. Use Cases

Slovenian partners within ECOLOOP will address the UCs presented in **Table 10.**

Table 10: SI pilot site UCs

UC ID	Name
UC SI.01	Optimize the operation and improve the security of supply of biomass centre Nazarje
UC SI.02	Utilization of flexibility of the biomass centre Nazarje
UC SI.03	Design of a modular biomass slow pyrolysis system solution
UC SI.04	Biochar maximum utilization
UC SI.05	Biomethane from biogas power plant utilization for agricultural machinery
UC SI.06	Redesign of subsidies and business models for biogas

UC SI.01 aims to optimize Biomass Centre Nazarje's energy system by integrating existing and new infrastructure like CHP units, wood chip boilers, EV charging, PV, and battery storage, to maximize market opportunities, operational efficiency, and security of supply. Additionally, it explores distributing excess heat to industrial zone end-users for environmental and social benefits.

UC SI.02 leverages biomass centre Nazarje's flexibility assets to provide ancillary services, enhancing grid stability and enabling passive monetization. Through the Kolektor sETup aggregation platform, historical data guides strategic bidding in ancillary services markets, unlocking the integration of more renewables.

Furthermore, **UC SI.03** designs a modular woody biomass power plant prototype, offering tailored solutions for small-scale users like sawmills or farms. The outcome will be a container-based CHP unit with basic specifications, showcasing the potential for scaling up to meet various energy needs.

UC SI.04 explores biochar production in CHP operations, examining temperature's impact on power output and byproduct yield. The analysis will assess biochar quality for potential agricultural applications, integrating its value into CHP profitability evaluation.

KIS operates a collaborative micro biogas plant, converting organic wastes into biogas to reduce emissions and support energy needs. **UC SI.05** will progress in biomethane production, employing a two-phase purification process to obtain high-purity methane for use as fuel, alongside generating organic fertilizer as a byproduct.

UC SI.06 aims to revolutionize the agricultural sector's energy landscape through innovative BMs and subsidies for biogas and biomethane production, aligning with sustainable development goals. The project targets carbon footprint reduction, energy self-sufficiency, and rural economic growth, utilizing innovative financial support and policy changes for biogas plants to create a scalable framework for widespread adoption.

The contribution of the described UCs to the ECOLOOP KERs can be seen in **Table 11**. The Slovenian pilot will be focusing on KER 1 "Innovative and efficient biogas production and conversion process", KER 1.1 "Flexibility management to increase the profitability of slow pyrolysis process", KER 2 "Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes", KER 3 "Bioproducts to create positive effects on soil health, biodiversity and groundwater" while also contributing to KER 6 "Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy".

Table 11: SI pilot site UC-KER mapping

	UC SI.01	UC SI.02	UC SI.03	UC SI.04	UC SI.05	UC SI.06
KER 1	▓				▓	
KER 1.1	▓	▓	▓	▓		
KER 2			▓	▓		
KER 3				▓		
KER 4						
KER 5						
KER 6						▓
KER 7						

3.4.3. Economic, Environmental and Social Impact

The implementation of the UCs will result in the following impacts on the environment, economy and social acceptance:

Environmental impact

- Technical and economic optimization of energy asset operations within **UC SI.01** will enable a CO_2 emission minimization strategy. This involves maximizing the utilization

of RES within the pilot site and capitalizing on market opportunities for buying energy derived from renewable sources, thereby positively impacting the environment.

- Harnessing flexibility in the ancillary services market within **UC SI.02** is instrumental in stabilizing the power grid, paving the way for increased deployment of RES within the system.
- The heightened adoption of modular biomass slow pyrolysis system solutions among smaller entities such as sawmills, farms, and other stakeholders within **UC SI.03** has the potential to amplify the generation of electricity and heat from RES. This, in turn, may diminish the reliance on conventional power plants, such as thermal power plants, and alleviate the strain on power networks - allowing more RES connections.
- The utilization of biochar within **UC SI.04** contributes to carbon removal, achieved by incorporating the produced biochar into the soil.
- The adoption of biomethane for agricultural machinery within **UC SI.05** holds significant environmental benefits by reducing the CO_2 emissions associated with conventional fuels.

Social acceptance

- Several UCs - **UC SI.03, UC SI.04, UC SI.05, and UC SI.06** - are poised to foster the creation of new jobs with higher added value, thus collecting positive approval from diverse communities, including the farming community.
- Through the optimal technical and economic optimization of energy asset operations within **UC SI.01**, the potential heat source for the community in the industrial zone Nazarje will be unlocked. This positive development is anticipated to benefit industrial zone customers by providing locally produced and affordable heat derived from RES.
- The implementation of **UC SI.02** is expected to alleviate the local power grid, creating room for increased investments in PV power plants or similar ventures. This, in turn, positions the project as a catalyst for the green transition in the area, gaining recognition and support.
- Several UCs - **UC SI.03, UC SI.04, and UC SI.05** - will actively encourage private investments in the further development of biomethane, modular CHP, and biochar (after the project establishes positive influences). These investments are poised to stimulate the prosperity and awareness of local communities and beyond and thus help with social acceptance.

Economic impact

- Optimal technical and economic management of the energy assets within **UC SI.01**, considering various markets, will unlock a lot of opportunities for BIOM to benefit from rising market opportunities. For example, balancing the energy consumption in the intraday market with the BESS could decrease balancing costs.

- Utilizing the flexibility of the energy assets in the ancillary services market within **UC SI.02** will offer additional streams of monetization and thus, for example, improve the ROI of the energy assets.
- The **UC SI.04** will present the additional revenue stream for the CHP operation, which could potentially increase the profitability and faster rate of return of the investment.
- Several UCs - **UC SI.03, UC SI.04, and UC SI.05** - will actively encourage private investments in the further development of biomethane, modular CHP, and biochar (if the project establishes positive influences). Additional investments and newly defined revenue streams will increase the profitability of the installations. These investments are poised to stimulate the prosperity and economy of local communities and beyond.

3.4.4. Use Case Revision

Table 12 provides an overview of the UC revision of the Slovenian pilot site. **Five UCs** in the Slovenian pilot are marked as innovative and therefore present added value to ECOLOOP, while **UC SI.02** is marked as not innovative. **UC SI.01** is innovative as it develops the model to simulate various aspects of cross-sector planning and optimally utilize market opportunities while considering security, technical and economic boundaries. **UC SI.03** will enable the production, design and sales of small modular CHP units, tailored to smaller sawmills and farmer needs. **UC SI.04** expands the business model (BM) of CHP operation from heat and energy generation to additional production of biochar as a result of CHP operation. **UC SI.05** introduces a new approach by leveraging biogas and biomethane production capabilities to power agricultural machinery. The **UC SI.06** is innovative by proposing new BMs and subsidy structures for biogas, addressing financial and operational barriers to renewable energy adoption.

However, the **UC SI.02**, even though marked as not innovative, includes the utilization of advanced machine learning algorithms and inclusion of availability, security, technical and economic boundaries and thus fully integrates a user-centric approach, which makes it significantly important for the Slovenian pilot.

Table 12: Slovenian UCs revision overview

Use Case ID	UC innovative?	If not innovative, UC necessary?
UC SI.01	Yes	/
UC SI.02	No	The UC includes the development of the baseline and flexibility model based on historical

		measurements while utilizing advanced machine learning algorithms. Furthermore, the UC includes availability, security, technical and economic boundaries and thus fully integrates a user-centric approach.
UC SI.03	Yes	/
UC SI.04	Yes	/
UC SI.05	Yes	/
UC SI.06	Yes	/

4. Requirements

The current section describes the work carried out by the consortium in the framework of T2.2, which resulted in the final list of requirements of the project.

The first section briefly describes how the Volere methodology was implemented for the project. The next section includes a summary of requirements per KER, while some additional statistics are provided in the last one. The full templates are available in Annex III: Requirements.

4.1. Requirements Specification Process

The Volere methodology as explained in **Section 2.2.1** was put into practice in T2.2 "Definition and consolidation of project requirements" to define and consolidate the list of requirements of the project. The timeline of the process is outlined in **Figure 17**.
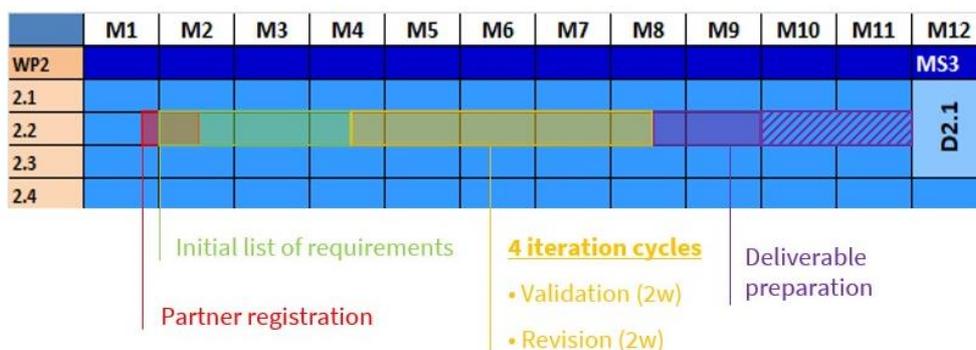
Figure 17: Timeline of T2.2

A **kick-off meeting** with all partners was held in **M1**, where a workshop took place on the Volere methodology and tool. All participants were encouraged to register in the tool in the following weeks and start providing their first inputs.

By **mid-M4**, the initial list of requirements was defined, and the first iteration cycle started. Each iteration took **4 weeks**, consisting of **2 weeks of validation** and **2 weeks of revision**. At the end of each cycle, a dedicated wrap-up telco was held to close any pending issues and start the next iteration. **4 full iteration cycles**—and a 5th short one to close pending issues— were completed, with active participation from all partners.

By **mid-M8**, the final list of requirements was consolidated, amounting to a total of 91 requirements. A summary of these requirements is provided in this section, while the full templates are available in **Annex III: Requirements.**

4.2. Summary of Requirements per KER

The ECOLOOP requirements were classified per KER, and this summary presents them as such in **Table 13**.

Table 13: Requirements for KER 1—Innovative and efficient biogas production and conversion process

Requirement ID	Description
K1_001	[UC SI.05] When the biogas plant is upgraded to produce biomethane, the produced biomethane shall comply with EU standards for automotive fuels (EN 16723-2:2018), ensuring its suitability for use in automotive engines.
K1_002	[UC ES.02] GENIA and INDEREN must request an Environmental Activity License at the location of the biogas pilot site.
K1_003	[UC ES.02] [UC SI.05] The biogas plant shall operate according to safety procedures.
K1_004	[UC ES.02] [UC ES.03] The anaerobic digestion process shall be optimized for maximum production of biogas and digestate for the production of biofertilizer.
K1_005	[UC ES.02] The biogas plant should be designed and implemented to be easily maintainable, ensure long-term operation efficiently and to reduce downtime.

K1_008	[UC SI.05] Implement an enhanced monitoring system for the biogas production process to optimize energy output.
K1_009	[UC SI.05] A monitoring system will be implemented in the second unit to calculate the production rate to biomethane.
K1_010	[UC SI.05] Enhance the biogas cleaning process to improve biomethane purity.
K1_011	[UC BG.02] The Biogas production system must be capable of processing diverse organic waste types from agriculture and local sources.
K1_012	[UC ES.02] The digester diet should be adapted to the waste generated at each stage of the growing cycle.
K1_013	[UC ES.02] The digester diet should be adapted to the waste based on the crops grown in the area.
K1_014	[UC SI.05] Develop and compile a comprehensive guidebook that serves for outlining the processes for initiating a biogas and biomethane plant project.
K1_015	[UC ES.02] Define the agriculture waste diet to include in the digestate.
K1_016	[UC ES.02] The system shall incorporate a monitoring equipment of control parameters (pH, oxygen, etc.).
K1_018	[UC ES.02] Define the responsibility of the operation and maintenance expenses of biogas Spanish pilot.
K1_019	[UC SI.05] Establish a training program for additional KIS staff on the operational management of the biogas to biomethane conversion process and machine refuelling.
K1_020	[UC SI.05] Agricultural machinery at KIS, when present, shall be adapted or retrofitted to run on biomethane, enabling efficient and sustainable agricultural tasks using biomethane as a fuel.
K1_021	[UC BG.01] Optimized energy output and yield makes highly qualified agricultural and biological engineers necessary.
K1_022	[UC ES.02] [UC SI.05] All operations within the biogas to biomethane conversion process must adhere to national and EU environmental and safety regulations.

The requirements for KER 1 focus on different aspects of the process of setting up biogas and biomethane production plants in the different pilots, from legal aspects (K1_001, K1_002), safety requirements (K1_003, K1_022), design and implementation (K1_005, K1_009, K1_016, K1_020), to their outputs and their optimization (K1_004, K1_008, K1_010). They are generally associated with UCs that implement the biogas and biomethane production plants and/or manage their output, namely:

- **UC ES.02:** Biogas/biomethane production from agricultural wastes.
- **UC ES.03:** Biofertilizers production from agricultural wastes.
- **UC BG.01:** Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes.
- **UC BG.02:** Regional agricultural and other waste analysis and potential biogas production.
- **UC SI.05:** Biomethane from biogas power plant utilization for agricultural machinery.

The requirements for **KER 1.1** are collected in **Table 14.**

Table 14: Requirements for KER 1.1—Flexibility management to increase the profitability of slow pyrolysis process

Requirement ID	Description
K11_004	[UC SI.01] [UC SI.02] The aggregator platform shall collect data from flexibility assets.
K11_005	[UC SI.01] [UC SI.02] The optimal technical and economic optimization calculation shall be executed in less than 15 minutes.
K11_006	[UC SI.02] The aggregator shall activate the flexibility asset, when the aggregator receives the signal from the system operator.
K11_007	[UC SI.01] When the operational set point is received from the aggregator, the maximal set-point error shall be 5%.
K11_009	[UC SI.02] The CHP is operating stable and efficient at variable temperature setpoints.
K11_010	[UC SI.03] CHP system components must have modular functionality in order to design several unit types in terms of power output and storage size.
K11_011	[UC SI.04] The designated CHP unit must allow Variable temperature setpoint operation.

KER 1.1 is very specific to the **Slovenian pilot** and thus, requirements define the necessities of their four first UCs:

- **UC SI.01:** Optimize the operation and improve the security of supply of biomass centre Nazarje.
- **UC SI.02:** Utilization of flexibility of the biomass centre Nazarje.
- **UC SI.03:** Design of a modular biomass slow pyrolysis system solution.
- **UC SI.04:** Biochar maximum utilization.

The requirements are mostly **functional, defining operational parameters of the biomass centre Nazarje and its CHP** units in order to maximize the potential flexibility for subsequent use to provide services to the System Operator and other stakeholders in the industrial zone.

The requirements for **KER 2** are collected in **Table 15.**

Table 15: Requirements for KER 2 ─ Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes

Requirement ID	Description
K2_001	[UC ES.01] The system shall effectively optimize the distribution of solar energy to cover the energy needs of geothermal energy.
K2_002	[UC ES.01] The system shall incorporate a real-time monitoring and adaptation mechanisms to achieve an optimal distribution of different renewable energies when energy demand and environmental conditions change.
K2_003	[UC ES.01] The system shall efficiently integrate Solar PV and Geothermal Energy to maintain optimal conditions for agricultural crops across different seasons.
K2_004	[UC ES.01] The system shall integrate various sensors tailored to address the specific needs of crops, including but not limited to moisture, temperature, and CO_2 sensors.
K2_007	[UC SI.01] The interoperability and interconnectivity of various RES technologies must be ensured.
K2_008	[UC BG.01] Publishing a catalogue of legal requirements for each Country to apply and to install RES.
K2_009	[UC BG.01] The new photovoltaics must be positioned to provide most possible output.
K2_010	[UC BG.01] The smart Agri-PV system shall be dimensioned so that the solar energy is able to cover the energy needs of the greenhouses.

K2_011	[UC BG.01] The smart Agri-PV system, in combination with the thermal energy system of the biogas plant shall automatically adjust to meet the energy demands of the greenhouses.
K2_012	[UC BG.01] The different RES must include real-time monitoring and an automatism to optimize the distribution of renewable energies, depending of requirements of the greenhouses.
K2_013	[UC BG.01] ALBENA's smart Agri-PV system, in conjunction with thermal energy from the biogas plant, shall provide optimal grow conditions for the greenhouses.

Requirements for **KER 2** define the details of the **combination of RES in the different pilot sites**, considering their particularities and objectives. They define the monitoring of RES and integration of technology (K2_002, K2_003, K2_004, K2_012), their optimal combination and interoperability (K2_001, K2_007, K2_011), as well as other legal and technical details. They are linked to three UCs from three pilots:

- **UC ES.01:** An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops.
- **UC BG.01:** Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes.
- **UC SI.01:** Optimize the operation and improve the security of supply of biomass centre Nazarje.

The requirements for **KER 3** are collected in **Table 16**.

Table 16: Requirements for KER 3 —Bioproducts to create positive effects on soil health, biodiversity and groundwater

Requirement ID	Description
K3_001	[UC ES.03] Farmers, cooperatives and irrigation communities must be interested in the application of the bioproducts generated.
K3_002	[UC ES.02] [UC ES.03] Definition of permitted substrates for obtaining digestate that can be used to produce a biofertilizer that can be commercialized.
K3_003	[UC BG.01] Soil investigation has to be made on every field, to have transparency about the status of the soil, and which ingredients need to be added, depending on the crop.

K3_004	[UC ES.04] [UC ES.05] The application of the product must cover the variety of crops in the area.
K3_005	[Global] If there are many farmers interested in having plots for experimentation, then selection criteria must be established.
K3_012	[UC EE.03] Novel biostimulant should increase the potential production of forest plantations.
K3_013	[UC EE.01] Recycling of wood ash from energy waste as biofertilizer should increase the potential production of forest plantations.
K3_015	[UC EE.01] The yield productivity data of plantations treated by wood ash must be collected.
K3_016	[UC EE.01] The effect of wood ash on biodiversity and environment of cut-away peatlands must be monitored.
K3_017	[UC EE.03] Environmental impact of biostimulant in comparison with conventional fertilization should be evaluated.
K3_018	[UC EE.03] Impact of biostimulant on soil organic carbon pools should be measured.
K3_019	[UC EE.04] Basic tree growth data must be collected from sample plots of different tree species plantations.
K3_020	[UC EE.04] The yield of plantations must be distributed into wood assortments.
K3_021	[UC ES.04] [UC ES.05] A preliminary analysis of soil should be carried out.
K3_022	[UC ES.04] [UC ES.05] Soil managers should know about soil indicators that they are testing.

For **KER 3**, the main focuses of the requirements are the **analysis and composition of the bioproducts produced** (K3_002, K3_004, K3_021), their objectives (K3_012, K3_013, K3_017), testing (K3_001, K3_005, K3_022), and evaluation (K3_015, K3_016, K3_019). The UCs they are included in are:

- **UC ES.02:** Biogas/biomethane production from agricultural wastes.
- **UC ES.03:** Biofertilizers production from agricultural wastes.
- **UC ES.04:** Enhancement of soil properties (agriculture-forestry) bioproducts validation.
- **UC ES.05:** Tests of the behaviour of the product in agronomic application.

- **UC BG.01:** Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes.
- **UC EE.01:** Wood ash recycling system for forest plantations.
- **UC EE.03:** New environmentally friendly biostimulants and fertilizers to enhance the production of forest plantations.
- **UC EE.04:** The potential wood production of different deciduous tree species on different soil types.

The requirements for **KER 4** are collected in **Table 17.**

Table 17: Requirements for KER 4—Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)

Requirement ID	Description
K4_001	[Global] The tool must prevent the access and use by unauthorized users by means of authentication mechanisms.
K4_002	[Global] The tool must support multitenancy.
K4_003	[Global] An identified user must only be able to access the information they are granted permission to.
K4_004	[Global] Measuring equipment in the pilots must have (or be complemented with) IoT capabilities in order to send (near) real-time data to the tool.
K4_005	[Global] The tool will provide a dynamic model of the pilots that includes their key elements and their current status.
K4_008	[UC ES.01] The tool will coordinate the optimal combination of PV, geothermal, and biogas systems in the greenhouse plant.
K4_009	[UC ES.03] The tool will integrate with the SCADA to operate over the biogas plant and its production (biogas, organic digestates).
K4_010	[UC BG.01] The decision support tool will integrate and manage the operation of the Agri PV greenhouses and their systems to ensure optimal energy use and crop growth conditions.
K4_011	[UC BG.02] The tool must incorporate biogas production models that allow different analysis on the technology.
K4_014	[UC ES.02] The system shall integrate a KPI monitoring module to continuously assess and analyse KPIs.

K4_015	[UC ES.01] The system shall include capabilities to monitor and analyse how diffuse radiation from solar PV panels affects crop production.
K4_016	[Global] The Decision Support System (DDS) tool for farmers and foresters should be easy to use by the different types of users.
K4_017	[UC EE.01] The tool must model the wood ash recycling process to provide an estimation of GHG reduction.

The requirements associated with **KER** 4 define the **functionalities of the Decision Support Tool for farmers and foresters, big data analytics, as well as the IoT ecosystem** necessary to retrieve measurements from the pilot sites. Some of the requirements are common to all pilots (security and privacy of the tool, measuring equipment capabilities, pilot modelling), while more specific functionalities are defined for each UC that the tool participates in, namely:

- **UC ES.01:** An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops.
- **UC ES.02:** Biogas/biomethane production from agricultural wastes.
- **UC ES.03:** Biofertilizers production from agricultural wastes.
- **UC BG.01:** Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes.
- **UC BG.02:** Regional agricultural and other waste analysis and potential biogas production.
- **UC EE.01:** Wood ash recycling system for forest plantations.

The requirements for **KER 5** are collected in **Table 18.**

Table 18: Requirements for KER 5 ⸺ Carbon sequestration tool calculation and renewable-based agricultural protocols

Requirement ID	Description
K5_001	[Global] Carbon calculator tool should be working online.
K5_002	[UC EE.02] The carbon calculator tool must integrate the pilot sites of Spain, Bulgaria and Slovenia.
K5_003	[UC EE.02] Carbon calculator for landowners and companies should estimate the potential profit from CO_2 fixation in marginal lands from wood production and carbon credit.

K5_004	[Global] The tool should operate without collecting, storing, or transmitting any personal data or user inputs.
K5_005	[Global] The carbon sequestration tool should be easy to use by the different types of users.
K5_006	[Global] Carbon calculator tool does not require user registration.
K5_007	[UC EE.04] The potential wood production of different deciduous tree species on different soil types must be monitored and modelled in Estonian conditions.

The **functionalities of the Carbon Sequestration Tool** are defined by the requirements associated with **KER 5.** Although mostly **focused on the Estonian pilot**, the tool will be tested in **all pilots**, so general technicalities (involving its deployment, data management, usability, etc.) are described as well. The specifically associated UCs are:

- **UC EE.02:** Carbon calculator for forest plantations.
- **UC EE.04:** The potential wood production of different deciduous tree species on different soil types.

The requirements for **KER 6** are collected in **Table 19.**

Table 19: Requirements for KER 6⸻Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy

Requirement ID	Description
K6_003	[UC SI.06] Implement a feedback mechanism for farmers and foresters to report on the usability of biogas technologies.
K6_004	[UC SI.03] For CHP modular unit design, the end customer must have historical data on thermal and electric consumption to properly size the CHP system.
K6_005	[UC SI.03] [UC SI.06] An overview of existing financing practices and schemes will be collected and provided to interested local communities and investors.
K6_006	[Global] Detailed economic cost breakdown with potential funding mechanisms will provide insights to end users and investors on the required RES investments in new innovative BMs.

K6_007	[UC BG.01] It needs to be analysed how Governments can economically support farmers, who install RES in combinations with or without back-up batteries.
K6_008	[UC BG.03] An analysis must be done in order to assess and provide insights on national and European regulations impacting the integration of Agri-PV combined with Biogas solutions.
K6_009	[UC ES.05] Contracts should be drawn up for the transfer of the biofertilizer validation plots by the farmers.
K6_011	[UC EE.02] The efficiency of the biorefinery production must be possible to assess on the basis of the feedstock properties of woody biomass from novel short-rotation forest plantations.
K6_012	[UC BG.03] TRU must develop a set of successful description of cooperative BMs and subsidy framework.
K6_013	[UC BG.03] Renewable energy cooperatives shall promote their innovative approach (logo, slogan, common brand).
K6_014	[UC BG.03] TRU must prepare a showcase of modular renewable energy technologies suitable for small-scale agricultural cooperatives.
K6_015	[UC BG.03] [UC SI.06] The project must align with existing agricultural and energy policies, and any efforts to redesign subsidies or introduce new BMs must be compliant with current legal frameworks.

Requirements for **KER 6** define the **necessities to engage farmers and foresters as prosumers of RES by establishing economic and social support mechanisms**. They consider different types of RES (K6_003, K6_004, K6_008), define the necessary analyses to implement the new measures (K6_005, K6_006, K6_007), and take into account the feedback of the users (K6_003, K6_014). They are linked to the following UCs in all four pilots:

- **UC ES.05:** Tests of the behaviour of the product in agronomic application.
- **UC BG.01:** Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes.
- **UC BG.03:** National and regional regulation and business model's implementation to foster rural development.
- **UC EE.02:** Carbon calculator for forest plantations.
- **UC SI.03:** Design of a modular biomass slow pyrolysis system solution.
- **UC SI.06:** Redesign of subsidies and business models for biogas.

The requirements for **KER7** are collected in **Table 20.**

Table 20: Requirements for KER 7—ECOLOOP-SOIL Living Lab

Requirement ID	Description
K7_001	[Global] Living Labs must integrate the stakeholders in the pilot area.
K7_002	[Global] If farmers with plots are not available, then the living lab will not be able to present experimental results.
K7_003	[Global] If there are many interested actors within an area, then selection criteria must be established.
K7_004	[UC ES.04] [UC ES.05] The bioproducts generated must improve soil quality.
K7_005	[Global] Soils must be monitored after the application of the bioproducts and strategies decided within the living lab activities in order to know their substantial improvement.
K7_006	[Global] The participation of many stakeholders in the living lab is key, and therefore, their satisfaction must be evaluated because the design of the activities must be carried out to facilitate a friendly, dynamic and potential work environment.
K7_007	[Global] The living lab is a space for generating and co-creating innovations, and results must be transferred to society.

Finally, **KER 7** establishes the **ECOLOOP soil Living Labs**, which are planned to be started in the **Spanish pilot**, and then **replicated in the other three**. Associated requirements define the participation of local stakeholders (K7_001, K7_002, K7_003), the output expected from the bioproducts tested (K7_004, K7_005), and the evaluation of the outcomes (K7_006, K7_007). Most of the requirements are global as they apply equally to all pilots, one being specifically linked to two UCs in Spain:

- **UC ES.04:** Enhancement of soil properties (agriculture-forestry) bioproducts validation.
- **UC ES.05:** Tests of the behaviour of the product in agronomic application.

4.3. Overall Statistics

Some statistics using different criteria are provided as a means of conclusion of **T2.2.**

A total of **91 requirements** were produced as the outcome of the task. Their classification per KER is provided in **Table 21**.

Table 21: Total requirements per KER

KER	Number of requirements
KER 1	19
KER 1.1	7
KER 2	11
KER 3	15
KER 4	13
KER 5	7
KER 6	12
KER 7	7

In general, all KERs are well-defined and represented by the requirements. Those KERs that will have specific implementations in different pilots need more requirements to capture their unique features, while those with the focus on one pilot with further replication in the rest **(KER 1.1 in Slovenia, KER 4 in Estonia, KER 7 in Spain)** have a shorter and more generic set of requirements.

The number of **requirements created per partner** is shown in **Table 22.**

Table 22: Total requirements created per partner

Partner	Number of requirements
ALBENA	11
AVA-ASAJA	4
BIOMASA	4
EULS	15

ETRA	12
FERT	1
GENIA	4
INDEREN	9
IRI UL	3
KIS	10
SETUP	4
TRU	3
UPV	11

The table makes it clear that all partners involved in T2.2 "Definition and consolidation of project requirements" had an active participation. It needs to be noted that these are the numbers from the final list, but other **requirements may have been removed at some point** in the iterative process. Moreover, participation in the validation and revision of requirements is not represented by these numbers. Regarding the **type of requirements**, the numbers are provided in **Table 23.**

Table 23: Total requirements per type

Type of requirement	Number of requirements
Functional and data requirements	43
Operational requirements	8
Legal requirements	6
Maintainability and support requirements	5
The purpose of the product	5
The client, the customer and other stakeholders	4
The scope of the product	4
Usability and humanity requirements	4
Users of the product	4
Performance requirements	2

User documentation and training	2
Cultural and political requirements	1
Relevant facts and assumptions	1
Security requirements	1
The scope of the work	1

The table clearly shows that the vast majority of requirements (more than **47%**) are **functional and data requirements**, defining the functionalities of the tools, the properties of the products, and the necessities in terms of measurements and data analysis. Other relevant types of requirements include **operational, legal, and those that involve the users and stakeholders** who will test the outcomes of the project. **Table 24** shows the **total number of requirements according to their priority.**

Table 24: Total requirements per priority

Priority	Number of requirements
5 (Highest)	62
4 (High)	26
3 (Medium)	3
2 (Low)	0
1 (Lowest)	0

It is revealed that **more than 68%** of the requirements are considered as the **highest priority**, a number that escalates to **more than 96% when combined with those with high priority.** This reflects the fact that T2.2 has provided very valuable outcomes that are essential to the successful completion of the project and the fulfilment of its objectives. Finally, the number of requirements per pilot and UC is provided in the table below (**Table 25**). It is to be noted that, as some requirements are associated with more than one UC, the numbers do not add up to the total amount of requirements.

Table 25: Total requirements per UC and pilot

UC	Number of requirements	Total requirements per pilot
UC ES.01	6	31
UC ES.02	12	

UC ES.03	4	
UC ES.04	4	
UC ES.05	5	
UC BG.01	10	
UC BG.02	2	17
UC BG.03	5	
UC EE.01	4	
UC EE.02	3	13
UC EE.03	3	
UC EE.04	3	
UC SI.01	4	
UC SI.02	4	
UC SI.03	3	24
UC SI.04	1	
UC SI.05	9	
UC SI.06	3	
Global	18	-

5. KPIs

Following the methodology described in **subchapter 2.3**, **16 project KPIs and additional 21 pilot specific KPIs** were identified in the process. The detailed descriptions of these KPIs are presented in **Annex IV: KPIs.**

5.1. Project KPIs

Table 26 shows the identified project KPIs. Moreover, the domain (environmental – ENV, social – SOC, economical – ECON, technical – TECH) of each KPI and mapping to pilot sites are listed.

Table 26: ECOLOOP's KPIs

No.	KPI ID	KPI Name	Domain	ES	BG	EE	SI
1	KPI_GA_01	Increase of the utilization of local zero- or low-carbon energy sources in project pilot sites	ENV	X	X		X
2	KPI_GA_02	Reduction of GHG emissions	ENV	X	X	X	X
3	KPI_GA_03	Increase of renewables in the energy mix of the project pilot sites	ENV	X	X		
4	KPI_GA_04	Increase of distributed RES capacity of the project pilot sites	SOC	X			X
5	KPI_GA_05	Reduction of energy costs in project pilot site	TECH	X	X		X
6	KPI_GA_06	Increase of energy self-consumption in rural areas	TECH	X			X
7	KPI_GA_07	Reduction of waste generation in agriculture and forest activities	TECH	X			

8	KPI_GA_08	Increase of the recycling and reuse of waste generation in agriculture and forest activities	TECH	X	X	X	
9	KPI_GA_09	Increase of profitability of waste generated in agriculture and forest activities	ECON		X		
10	KPI_GA_10	Increase yield productivity using biofertilizers instead of chemical fertilizers	ECON	X		X	
11	KPI_GA_11	Reduce groundwater contamination	ENV	X	X	X	
12	KPI_GA_12	Reduce the cost of fertilizers	ECON	X		X	X
13	KPI_GA_13	Reduce of chemical fertilisers use	ENV	X	X	X	X
14	KPI_GA_14	New jobs created in the pilot sites area	SOC	X			X
15	KPI_GA_15	Number of regulatory barriers and gaps identified and analysed in project pilot sites	SOC	X	X	X	X
16	KPI_GA_16	Number of policy recommendations provided at pilot sites project level	SOC	X	X	X	X
17	KPI_ES_1	Vegetative development of plants	TECH	X			
18	KPI_ES_2	Soil quality indicator improvement	TECH	X			
19	KPI_ES_3	Increase biogas production in rural areas	TECH	X			
20	KPI_ES_4	Digestate Transformation	TECH	X			
21	KPI_ES_5	Digestate ratio in biofertilizer	TECH	X			
22	KPI_BG_1	Percentage Increase in Biogas Production from Agri-Waste	TECH	X	X		
23	KPI_EE_1	Wood production of forest plantations in Estonian conditions	ECON			X	
24	KPI_EE_2	Biostimulant CO_2 gain at the ecosystem level in forest plantations	ENV			X	

25	KPI_EE_3	Biostimulant growth and yield gain in forest plantations	ENV			X	
26	KPI_EE_4	Biorefinery´s feedstock properties of woody biomass in forest plantations	TECH			X	
27	KPI_EE_5	User evaluation of the Carbon Calculator	TECH	X	X	X	X
28	KPI_EE_6	Nutrient-rich wood ash CO_2 gain at the ecosystem level in forest plantations on organic soils	ENV			X	
29	KPI_EE_7	Nutrient-rich wood ash effect on the production in forest plantations growing on organic soils	ENV			X	
30	KPI_Sl_1	Data collection reliability	TECH				X
31	KPI_Sl_2	Potential Growth in Stakeholder Engagement	SOC				X
32	KPI_Sl_3	Biomethane production rate	TECH	X			X
33	KPI_Sl_4	Biomass conversion efficiency in biochar production	TECH				X
34	KPI_Sl_5	Biomass conversion efficiency in power and heat generation	TECH				X
35	KPI_Sl_6	Bid success rate	TECH				X
36	KPI_Sl_7	Activation success rate	TECH				X
37	KPI_Sl_8	Set-point success rate	TECH				X

6. Conclusion

This document offers an overview of the work undertaken within the scope of T2.1 "Pilot site analysis and co-creation of project scenarios and UCs", T2.2 "Definition and consolidation of project requirements", and T2.3 "KPI identification and monitoring preparation". The methodology chapter provides insight into the **methods and sequence of the steps taken to collect inputs from ES, BG, EE and SI pilots** on pilot site analysis, UC definition, economic, environmental and social impact, UC revision, the definition of requirements and identification of KPIs.

Pilot site analyses include a **description of the site and its main function, a description of the pertinent energy or other assets and a description of ECOLOOP activities**. UCs were developed with **Trello** and expanded with a dedicated template to provide a detailed description, sequence diagram and relation to project KERs. The impact of the UCs was analysed in a **qualitative economic, environmental and social impact analysis**. In the last stage, the UCs revised using a dedicated template to assess their **level of innovation** and determine whether they should be left as it is, modified, or removed.

In parallel the **iterative process** was undertaken **in Volere** to define the requirements needed for individual UCs. The whole process was wrapped up with the identification of KPIs for evaluating the project's outcomes.

Spanish pilot highlights innovative approaches in agriculture to **enhance sustainability and energy efficiency**. These include **Agri-PV systems** integrated with **geothermal and biogas** technologies, **compact biogas plants** for processing agricultural waste, and the utilization of **biogas for soil improvement**. These initiatives aim to address waste management, soil degradation, and productivity enhancement, demonstrating the potential for greener agriculture practices.

Bulgarian partners indicate efforts to **enhance sustainability in agriculture** through various initiatives. These include integrating **PV and thermal energy from biogas plants** into greenhouses, **researching local agricultural waste for biogas potential**, and **analysing regulations** to promote renewable energy adoption. Through these endeavours, the aim is to optimize agricultural production, minimize emissions, and foster a more sustainable agricultural sector.

Estonian pilot aims to **enhance sustainability and productivity in forestry** through various initiatives. These include utilizing **wood ash** to support tree growth, developing a **carbon sequestration calculator** for forest plantations, and **investigating biostimulants** and fertilizers impact on forest growth.

The **Slovenian pilot** focuses on a multifaceted approach to **optimizing energy systems and promoting sustainability** in Biomass Centre Nazarje and the agricultural sector. Initiatives include integrating **IT infrastructure** for exploiting technical and market opportunities while ensuring grid stability, designing **modular woody biomass power plants**, and advancing **biomethane production**. These efforts aim to reduce carbon footprint, promote energy self-sufficiency, and foster rural economic growth through innovative BMs and policy changes. Furthermore, the biogas power plant will be expanded to include a biomethane unit, and the produced biomethane will be tested as a fuel for agricultural machinery.

The contributions from the consortium presented in this deliverable will serve as a **basis for the development and implementation of ECOLOOP innovation** while pursuing ECOLOOP's KERs. The defined UCs and requirements are crucial for the development of WP3 "Efficient production of renewable energy in agriculture and forestry sectors", WP4 "Renewable-based agricultural protocols and decision support tool for farmers and foresters" and WP5 "Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy". The KPIs will be monitored and considered in the WP7 "Project impact evaluation and replication strategy".

7. References and Acronyms

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7.1. Acronyms

Acronym	Description
AD	Anaerobic digestor
ALBENA	Albena AD
AVA-ASAJA	Asociacion Valenciana de Agricultores
BESS	Battery Energy Storage System
BG	Bulgaria
BIOMASA	Biomasa družba za trgovino, servis in montažo kotlov na biomaso d.o.o.
BM	Business model
CHP	Combined heat and power

CSV	Comma-separated value
D	Deliverable
DSS	Decision Support System
EE	Estonia
ES	Spain
ETRA	Etra Investigacion y Desarrollo, S.A.
EULS	Eesti maaulikool
FERTINAGRO	Fertinagro Biotech, S.L.
FIBENOL	Fibenol OU
GENIA	Genia bioenergy, S.L.
GUI	Graphical user interface
INDEREN	Ingenieria y desarrollos renovables, S.L.
IRI UL	Inovacijsko-razvojni institut Univerze v Ljubljani
KER	Key Exploitable Result
KIS	Kmetijski inštitut Slovenije - Agricultural Institute of Slovenia
KPI	Key Performance Indicator
M	Month
PV	Photovoltaic
RES	Renewable Energy Source
RMK	State forest management centre
SETUP	Kolektor seETup, storitve energetskega upravljanja, d.o.o.
SI	Slovenia
SIAR	Agroclimatic Information System for Irrigation
TRU	Trakiyski universitet
UC	Use Case
UPV	Universitat politecnica de Valencia
WP	Work Package

8. Annex I: Use Cases

8.1. ES pilot

UC ES.01	An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops
Description	The Spanish pilot site located in Horta Sud (Picassent), in the Valencia Region, will feature an installed power capacity of 1.5 MW connected to the energy grid. This initiative integrates a greenhouse configuration with geothermal and biogas production facilities to create a sustainable Agri-PV system. The project will follow the "renewable energy community model" and focus on cultivating sub-tropical, vineyard, and horticultural crops. PV description: • Area: Land 500 m^2 and Cover 80 m^2 (over existing buildings). Panels 320 m^2 • Power of the PV solar system: 70 kW • Energy generated by the PV system: 105 MWh • PV technologies: Bifacial PV technology The hybridization of Agri-PV and geothermal energy involves utilizing energy generated from solar panels for various purposes, including powering the geothermal system, providing air conditioning, supplying hot water for Agri-PV structures, supporting mushroom cultivation, maintaining refrigerators for fruit storage, and heating water for restroom facilities. This integrated system will operate as a closed circuit to maintain consistent temperatures in mushroom houses and greenhouses. Specifically for mushroom houses, this setup will enable year-round production stability without being sensitive to fluctuations in energy costs. Additionally, the system will provide heating for offices and domestic hot water (DHW) for restrooms and laboratory use. A 30kW heat pump will be employed to fulfil the total thermal needs of 101.52 kW/m^2.
Actors included	• Renewable energy company (INDEREN) • Farmers association (AVA ASAJA) • Research institution (UPV) • Sustainable fertilizers producer (FERTINAGRO) • Energy solutions provider (ETRA)
Triggering Event	Increase crop productivity and reduce energy costs.
Related Use Cases	UC ES.02 Biogas biomethane production from agricultural wastes

	UC ES.03 Biofertilizers production from agricultural wastes
	UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation
	UC ES.05 Tests of the behaviour of the product in agronomic application
Related ECOLOOP Innovations	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
	KER 4: Decision support tool for farmers and foresters
	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Pre-condition	• Optimal conditions for crop development and geothermal necessities
	• Availability of the land and legal permissions
	• Agreements with the final consumers and/or representatives
	• Necessary paperwork to connect the plant to the grid
Post-condition	Increased productivity of crops, generated energy and reduced costs linked to agriculture.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Agri-PV (energy and crops)	Discuss optimal conditions for agri-PV system. Development and needs of crops and energy production.	Optimal conditions for crop development, crop requirements and effects to implement the panels on the crop	INDEREN	UPV
2	Geothermal System	Define the thermal needs of crops for the development of geothermal energy	Optimal conditions and thermal necessities for crops development. Calculations for the installation of geothermal energy	INDEREN	UPV

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3	Develop and construction Agri-PV and Geothermal Systems	Coordination of the development of Agri-PV and geothermal systems for the pilot site.	Agri-PV and geothermal system specifications construction progress, site details	INDEREN	UPV AVA-AVASAJA GENIA ETRA FERTINAGRO
4	Connect to the Energy Grid and Implement Bifacial PV Technology	The 1.5 MW Agri-PV system is connected to the energy grid. Bifacial PV technology is implemented.	Grid connection details Implementation details	INDEREN	UPV
5	Integrate Agri-PV and Geothermal Systems	Energy generated is used for geothermal systems, air conditioning, hot water for Agri-PV structures, mushroom cultivation, chambers, and refrigerators.	Integration details	INDEREN	UPV
6	Implement Closed Circuit for Temperature Control	Maintain constant temperatures in mushroom houses and greenhouses.	Implementation details	INDEREN	UPV ETRA

Use Case sequence diagram
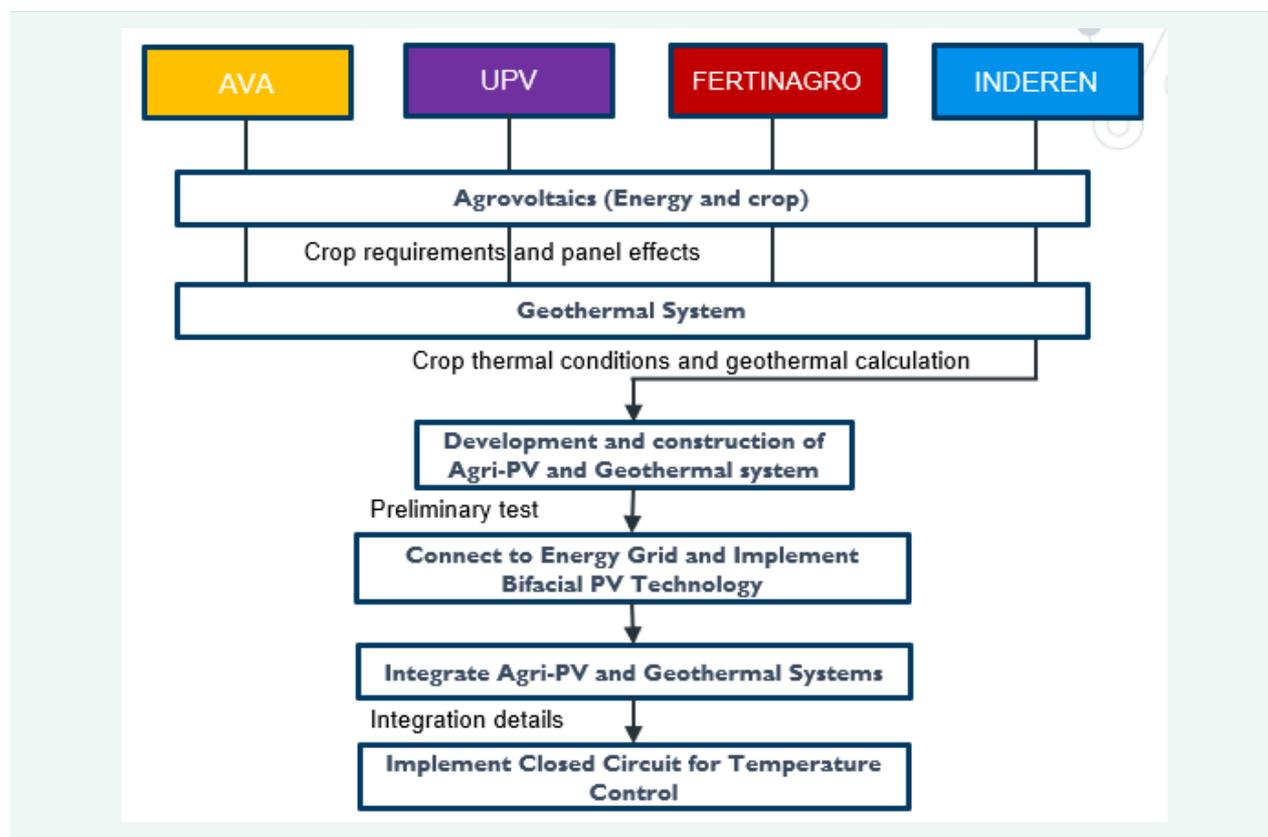
Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1a	Sub-optimal Crop Conditions	If optimal conditions for crop development are not met, leading to sub-optimal crop conditions.	Sub-optimal conditions	INDEREN	UPV

Realization	
Main responsible partners (Author)	• INDEREN
Contributing partners	• UPV • AVA-ASAJA • FERTINAGRO • ETRA

Priority	High

UC ES.02	Biogas/biomethane production from agricultural wastes
Description	This pilot site, established in the town of Beniparrell, will include a biogas plant based on a modular and compact design devoted to managing agricultural wastes from crops. The biogas plant will include an anaerobic digester (AD) where local agricultural biowaste will be treated. The design of the AD includes characterization of the agricultural residues and the organic fraction of urban solid waste to be digested, design of the anaerobic digester, design of the waste pre-treatment to be digested, biogas unit treatment design, auxiliary systems design and design of the process control system. The AD will meet the following requirements: • Working capacity: 3 to 4 tonnes of agricultural waste daily. • Biogas production: 7 to 8 Nm^3/h. • Biomethane production for sustainable transport in the region. • CO_2 production for Agri-PV greenhouse fertilization. • Bio-fertilizers production from digestate, UC ES.03.
Actors included	• Farmers association (AVA-ASAJA) • Biogas production solution provider (GENIA) • Renewable energy company (INDEREN) • Energy solutions provider (ETRA)
Triggering Event	The need for a sustainable waste-to-energy solution for efficient agricultural residue management and renewable energy production.
Related Use Cases	UC ES.01 An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops UC ES.03 Biofertilizers production from agricultural wastes UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation
Related ECOLOOP Innovations	KER 1: Innovative and efficient biogas production and conversion process KER 2. Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes KER 4: Decision support tool for farmers and foresters
Pre-condition	• Get the location of the facilities and the agricultural wastes available in the vicinity of the pilot site.

	• Establish agreements with potential farmers and other stakeholders located in the pilot installation area to supply the waste necessary to generate biogas/biomethane • Obtain legal permissions to install the biogas plant in the defined location.
Post-condition	• Validated biogas technology implementation. • Successful biomethane production from agricultural residues. • Establishment of a sustainable waste-to-energy system.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Characterization of the residue and design of the AD	Characterization of agricultural residues, designing the anaerobic digester, planning waste pre-treatment, and outlining biogas unit treatment.	Characteristics of agricultural residues, anaerobic digester design, waste pre-treatment plan, biogas unit treatment plan.	AVA-ASAJA GENIA INDEREN	All stakeholders of the UC
2	Construction and operation of the biogas plant	The anaerobic digester is built and put into operation.	Progress updates, operational data.	GENIA INDEREN	All stakeholders of the UC
3	Biogas and biomethane production.	The production meets the specified daily capacity and quality standards.	Biogas and biomethane production data and quality.	GENIA INDEREN	GENIA INDEREN
4	Self-consumption of biogas and biomethane	Self-consumption is achieved by produced biogas and biomethane	Utilization reports, efficiency metrics	GENIA INDEREN	All stakeholders of the UC

Use Case sequence diagram
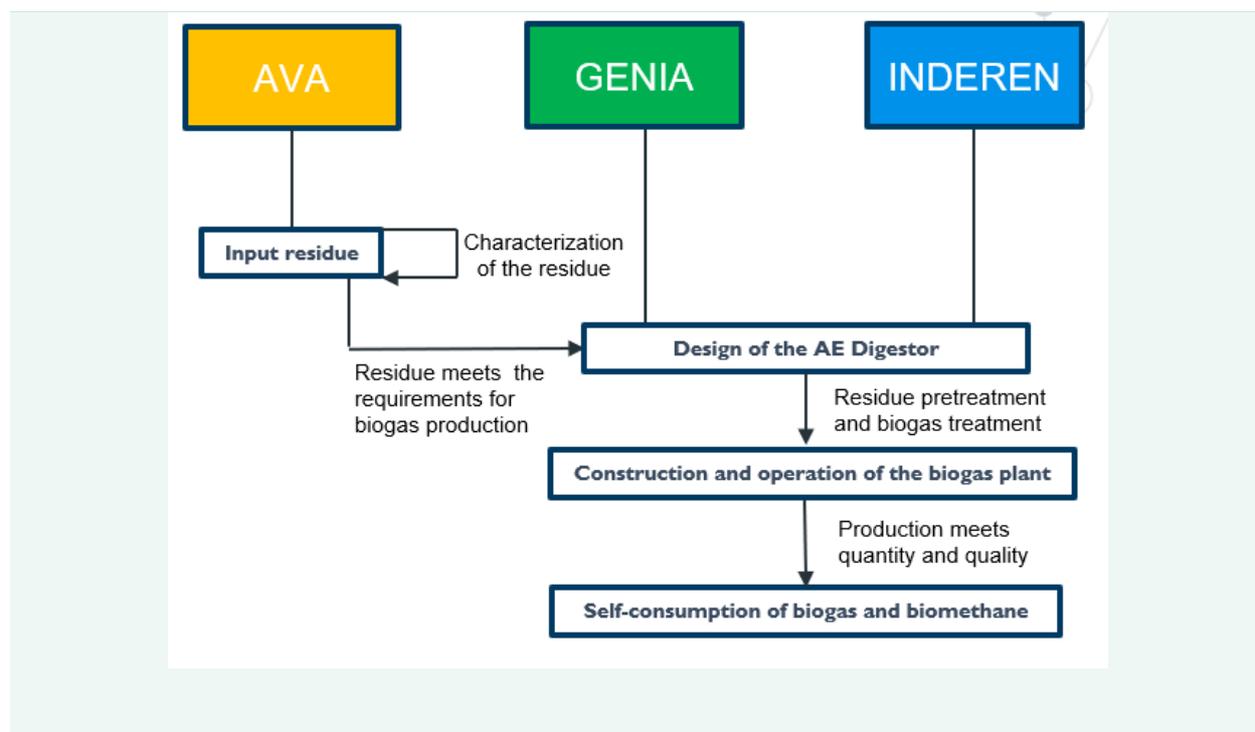
Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
2a	Equipment malfunction or system failures	Process control system detects equipment malfunction or system failure.	Alert details	Process Control System	GENIA
2b	Invalid agricultural residue input	Agricultural waste input is not within the acceptable range.	Quality of agricultural residues	AVA-ASAJA	GENIA
3a	Biogas production out of the specified range	Biogas production falls outside the specified range of 7-8Nm³/h	Biogas production details	GENIA	GENIA AVA-ASAJA
3b	Biomethane production issues	Issues with the biomethane production system, such as	Biomethane production details	GENIA	GENIA AVA-ASAJA

		insufficient purification or separation.			
2c	Safety Protocols Activation	Process control system activates safety protocols due to safety concerns or breaches of operational limits.	Safety protocol details	Process Control System	GENIA

Realization	
Main responsible partners (Author)	• GENIA
Contributing partners	• ETRA • GENIA • AVA ASAJA
Priority	High

UC ES.03	Biofertilizers production from agricultural wastes
Description	This UC will include a biogas plant where organic wastes will be treated and will produce digestates in addition to biogas. In the frame of the project, a nutrient recovery system will be implemented in the biogas pilot site, located in Beniparrel, for biofertilizer production. These organic digestates will be analysed and treated to get organic biofertilizers with high nutrient value. In addition, soil improvers will be generated to be applied in forestry conditions. Biofertilizers prepared for field application will be obtained as the main outcome according to the target crops selected from the study area and soil improvers for application in forest plots.
Actors included	• Sustainable fertilizers producer (FERTINAGRO) • Farmers association (AVA-ASAJA) • Research institution (UPV) • Renewable energy company (INDEREN) • Biogas production solution provider (GENIA) • Energy solutions provider (ETRA) • End-users • Agricultural cooperatives • Irrigation communities • Forest management companies
Triggering Event	• Digestate production in the UC ES.02

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	• Needs of farmers to fertigate their crops and of foresters to improve forest areas
Related Use Cases	UC ES.02 Biogas biomethane production from agricultural wastes UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation UC ES.05 Tests of the behaviour of the product in agronomic application
Related ECOLOOP Innovations	KER1: Innovative and efficient biogas production and conversion process KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater KER 4: Decision support tool for farmers and foresters KER 7: ECOLOOP-soil Living Lab
Pre-condition	• Characteristics of the digestate inputs, study area and target crop • Agreements with farmers to fertigate their crops with organic biofertilizers
Post-condition	Bioproducts developed for farmers and foresters

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Digestate analyses	Analysis of digestate (solid and liquid)	Physical-chemical properties of digestate	FERTINAGRO	AVA-ASAJA UPV GENIA ETRA INDEREN
2	Data collection from agricultural plots and crop distribution in the pilot area	Definition of target crops on which to apply biofertilizers	Database of farms in the pilot area with their extension, crops, irrigation system, management, etc.	AVA-ASAJA	FERTINAGRO UPV GENIA ETRA INDEREN

3	Identification of forest plots	Definition of forestry areas	Database of forestry areas in the pilot area (extension, forestry species, erosion situation, etc.)	UPV	AVA-ASAJA FERTINAGRO GENIA ETRA INDEREN
4	Identification of crop and forest plant needs	Definition of needs per plant	Database with needs per plant and management within the pilot area	UPV AVA-ASAJA	FERTINAGRO GENIA ETRA INDEREN
5	Production of biofertilizers and soil improvers	Development and preparation of bioproducts	Product and chemical composition	FERTINAGRO	UPV AVA-ASAJA GENIA ETRA INDEREN
Use Case sequence diagram					

Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths.					

Realization

Main responsible partners (Author)	• FERTINAGRO
Contributing partners	• AVA-ASAJA • UPV • ETRA • INDEREN • GENIA
Priority	High

UC ES.04	Enhancement of soil properties (agriculture-forestry) bioproducts validation
Description	Agriculture intensification, soil degradation, and climate change are harming soil health and crop yields. To counter this, innovations are shifting from chemical fertilizers to using agricultural waste for compost, improving productivity and soil quality. Enhanced bioproducts also offer better solutions for plant growth and soil health than traditional biostimulants. This UC would cover two of the most critical challenges of the Spanish pilot: reactivating agricultural activity and improving the content of organic matter in the soil. On the one hand, by evaluating the capacity of a new bioproduct obtained with agricultural residues from the area of influence of the pilot to improve the productivity of low-quality or degraded soils (agricultural abandonment or fires). On the other hand, by aligning conventional agriculture with the new trends of circular and green agriculture, improving the soil's biological, chemical, and physical quality with less use of inputs (nutrients of chemical or agrochemical origin, and/or water, where applicable). The main outcome of the UC is the improvement of soil indicators (organic matter, physical properties, etc.) in agricultural and forestry plots.

| Actors included	- Sustainable fertilizers producer (FERTINAGRO) - Farmers association (AVA-ASAJA) - Research institution (UPV) - Biogas production solution provider (GENIA) - Energy solutions provider (ETRA) - Renewable energy company (INDEREN) - End-users - Forest management companies - Agricultural cooperatives - Spanish Soil Scientific Society
Triggering Event	Increase soil quality
Related Use Cases	UC ES.01 An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops UC ES.05 Tests of the behaviour of the product in agronomic application
Related ECOLOOP Innovations	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater KER 7: ECOLOOP-soil Living Lab
Pre-condition	Plots and bioproduct availability
Post-condition	Improvement of soil conditions

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Greenhouse tests	Impact of bioproducts on soil properties	Physical-chemical properties of soil	UPV	AVA-ASAJA FERTINAGRO GENIA ETRA INDEREN
2	Bioproduct application protocol	Determine the dose and management for the best bioproduct application	Doses and management	UPV AVA-ASAJA FERTINAGRO	GENIA ETRA INDEREN
3	Soil preconditions evaluation	Analysis of soil samples at the	Physical-chemical properties of soil	UPV	AVA-ASAJA FERTINAGRO

					GENIA
		beginning of the experience			ETRA
					INDEREN
4	Readjustments and improvements of the bioproduct	Evaluation of bioproducts	Improvement characteristics	FERTINAGRO UPV	AVA-ASAJA GENIA ETRA INDEREN
5	Soil application and evaluation	Application of the bioproduct in agricultural and forestry plots	Physical-chemical properties of soil	UPV	AVA-ASAJA FERTINAGRO GENIA ETRA INDEREN

Use Case sequence diagram

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths.					

Realization

Main responsible partners (Author)	• UPV
Contributing partners	• AVA-ASAJA • FERTINAGRO • ETRA • INDEREN • GENIA
Priority	High

UC ES.05	Tests of the behaviour of the bioproducts in agronomic application
Description	The primary purpose of this UC is to carry out a Living Lab (UPV) to test the benefit of returning the harvest debris to the fields and thereby validate the formulation proposals for the improved digestate. To achieve this, a sprouting test will be conducted in the ECOLOOP SOIL Living Lab, using both a controlled environment chamber and laboratory conditions. The product's effectiveness will be evaluated during the seed germination phase and from transplant or sowing through the early vegetative stages, where plants have the highest nutritional and water demands, ensuring their immediate response. A secondary goal is to identify the optimal agronomic management practices for the different formulations of recovered digestate. All tests will consider the soil characteristics and crop requirements within the project's area of influence, as well as conventional management practices used there. Key indicators of success include: • Impact of digestate application on the morphological traits of horticultural plants, such as root and shoot size and weight, yield, and nutrient or metabolite content across growth stages (germination, early development, and full cultivation). • Improvement in soil physical-chemical properties post-application, including infiltration rate, porosity, aggregate stability, respiration rate, organic carbon levels, and nutrient content, alongside microbiota reactivation (e.g., respiration or enzyme activity). All the trials will have a design with sufficient statistical robustness to evaluate the efficacy of the different variants, which must be characterized to know their main characteristics. Each treatment will be applied in random blocks with a combination of crops and/or specific agronomic management conditions. All soil and plant samples, with and without treatments, will be subjected to the same analytical determinations.
Actors included	• Sustainable fertilizers producer (FERTINAGRO) • Farmers association (AVA-ASAJA) • Research institution (UPV) • Biogas production solution provider (GENIA) • Energy solutions provider (ETRA) • Renewable energy company (INDEREN) • End-users • Agricultural cooperatives

Triggering Event	• Use the bioproduct with high nutrient content generated and improved from the biogas generation plant
Related Use Cases	UC ES.03 Biofertilizers production from agricultural wastes UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation
Related ECOLOOP Innovations	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater KER 7: ECOLOOP-soil Living Lab
Pre-condition	• Plots and bioproduct availability
Post-condition	• Improvement of agronomic parameters

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Characterization of the physical environment	Definition of climate, geology, and geomorphology of the area where the plots will be located	General description of the area	UPV	AVA-ASAJA FERTINAGRO GENIA ETRA INDEREN
2	Greenhouse tests	Impact of bioproducts on germination and development parameters	Data on germination and plant development of horticultural plants	UPV	AVA-ASAJA FERTINAGRO GENIA ETRA INDEREN
3	Readjustments and improvements of the bioproduct	Evaluation of bioproducts	Improvement characteristics	UPV AVA-ASAJA FERTINAGRO	GENIA ETRA INDEREN
4	Identification of plots for "in situ" trials	Location of plots	X and Y coordinates and specific characteristics	AVA-ASAJA UPV	FERTINAGRO GENIA ETRA INDEREN
5	Bioproduct application protocol	Determine the dose and management	Doses and management	UPV AVA-ASAJA	GENIA ETRA

		for the best bioproduct application		FERTINAGRO	INDEREN
6	Application and evaluation of crops evolution	Application of the bioproduct in agricultural plots	Crop development control	UPV AVA-ASAJA	FERTINAGRO GENIA ETRA INDEREN

Use Case sequence diagram

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information

No exception paths.

Realization	
Main responsible partners (Author)	• UPV
Contributing partners	• AVA-ASAJA • FERTINAGRO • ETRA • GENIA • INDEREN

Priority	High

8.2. BG pilot

UC BG.01	**Smart Agricultural PV Greenhouses and scale-up in combination with thermal energy**
Description	ALBENA is located in the Dobrich region in northeast Bulgaria. It will optimize greenhouses shadowed and supplied by Photovoltaics. In combination with thermal energy produced by the existing biogas plant, ALBENA will develop Greenhouses into smart Greenhouses to raise the annual yield cycles and to raise agricultural production by reducing CO_2 emission.
	The Bulgarian pilot plans to refurbish existing greenhouses and possibly even install new greenhouses in future. The existing greenhouses will be equipped with approximately 20-40 kWp PV modules.
	Furthermore, additional rooftop photovoltaics on existing agricultural buildings will be installed to drive the processes with measurably reduced CO_2.
	Controllers and monitoring systems will be installed to observe the energy production, indoor parameters, and yield. The task is to raise the yield cycles per annum, while being independent from local utilities.
	The PV modules on both, the Greenhouses and the concrete rooftops will be installed in optimal two azimuth directions, East and West. Installations like this can spread the renewable energy production over the whole working day. The reached peak will be not only for a short time window, but over several hours.
	The combination of RES of the PV systems and the thermal energy from the biogas plant will enable ALBENA to increase the yield to more than one cycle per year, to dry fruit, as well as to heat office buildings and even to run machinery in a CO_2-free way.
	In periods of extremely high electricity prices, the farmers can switch completely to renewable energy and reduce farming costs measurably.
Actors included	• Plant owner (ALBENA) • Research institution (TRU)
Triggering Event	Reduction of CO_2 emission in agriculture, the need for reduction of energy costs, and raise of yield to several cycles per year by reducing electricity costs.
Related Use Cases	UCB G.02 Regional agricultural and other waste analysis and potential biogas production UC BG.03 National and regional Regulation and business models' implementation to foster rural development
Related ECOLOOP Innovations	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes

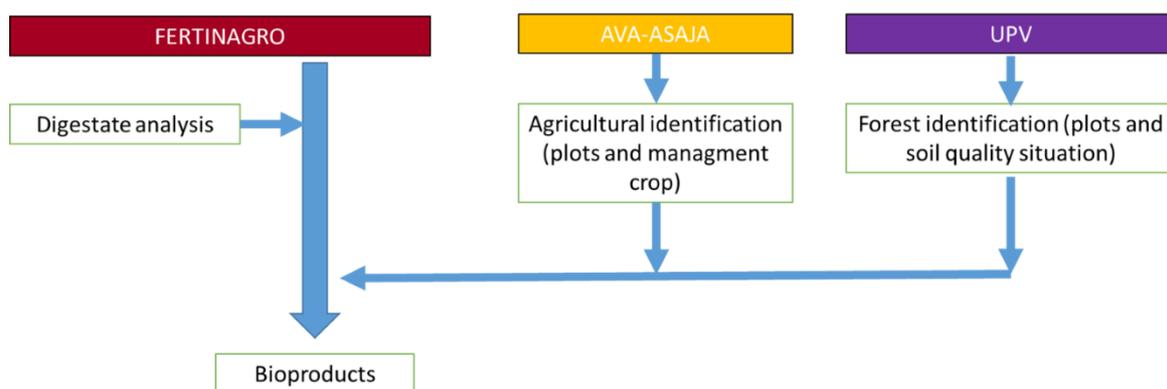|	KER 4: Decision support tool for farmers and foresters
Pre-condition	• The greenhouses operate with electricity provided by the utility grid. • The greenhouses operate without automatic regulation of optimal temperature. • The greenhouses have only one cycle of yield per year.
Post-condition	• Implementation of smart greenhouse to provide conditions for better usage of PV and thermal energy. • The greenhouses operate with electricity provided by PV which is CO_2 free. • Controllers and monitoring systems provide automatic regulation of the required conditions for the greenhouses. • The greenhouses have more than one cycle of yield per year.

Basic paths

Step No.	Event	Description of process /activity	Info. Exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Decision finding for suitable location	Decide for locations of greenhouse/PV System.	Locate suitable sites with east-west orientation and minimum 1500 m^2 of space for buildings with concrete rooftops and 140 m^2 of space for greenhouses	ALBENA	ALBENA
2	Decision finding for Crop	Selecting which crops will be cultivated in the GH	Which Crop gives highest yield, with highest sales revenue	ALBENA	ALBENA
3	Designing Greenhouse-Heating System	Define the thermal needs of crops for the layout of thermal energy	Calculations for the Layout and installation of thermal energy	ALBENA	ALBENA
4	Designing/ Refurbishing Greenhouses/Agri PV System based on gathered data and needs.	Coordination of the development of Agri-PV and thermal systems for the pilot site.	Technical specifications.	ALBENA	ALBENA
5	Construction works of the greenhouses	Installation of PV Module support and warm water system	As Built documentation	ALBENA	ALBENA

6	Commissioning of Thermal and PV system	Agri PV systems have been installed and commissioned.	Amount of electricity and thermal energy being produced and consumed, depending on outside temperatures	ALBENA	ALBENA, TRU
7	Software Integration	Integrating the software and going into automatic modus	Give necessary information for monitoring of agri-PV performance of crops production	ALBENA	ECOLOOP PARTNERS DEVELOPING KER 4
8	Optimization phase	Stepwise optimization of parameters and documentation of changes/consequences	Short term: which parameters provide best possible environment inside the GH; long-term: which parameters provide the highest yield	ALBENA	All Stakeholders

Use Case sequence diagram
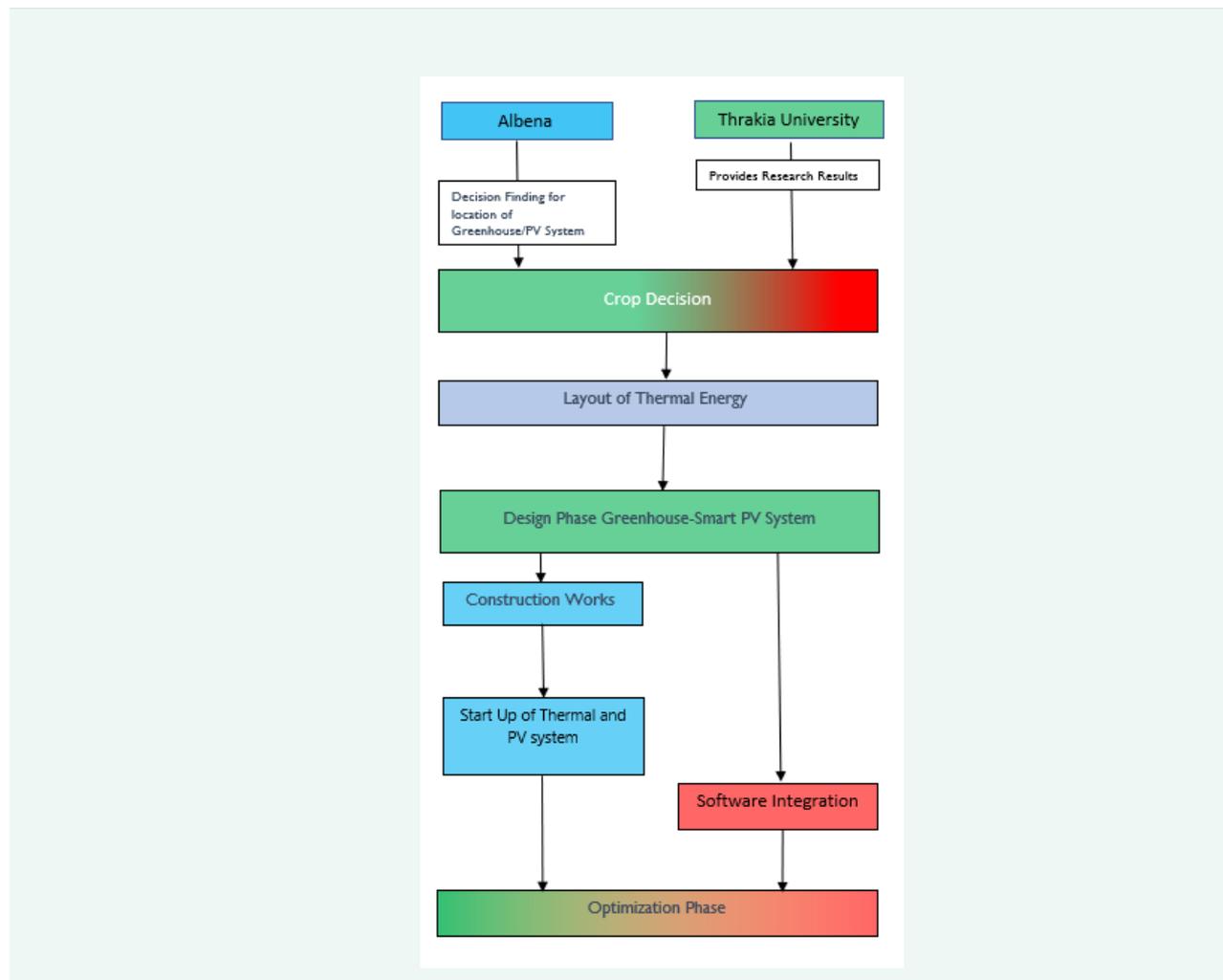
Exception paths

Step No.	Event	Description of process / Activity	Info. Exchanged	Actor producing the information	Actor receiving the information

No exception paths.

Realization	
Main responsible partners (Author)	• ALBENA
Contributing partners	• TRU
Priority	High

UC BG.02	Regional agricultural and other waste analysis and potential biogas production
Description	ALBENA and TRU are collaborating on a research project aimed at exploring the biogas production capabilities of regional agricultural and other organic wastes. This research will extend to the importation and cultivation of plants as potential energy crops to diversify biogas feedstocks. Samples of these materials will be assessed for their biogas production and mixture potential. The scalability of biogas production using these diversified feedstocks will be evaluated, and the resulting biogas yields will be tested in a real biogas power plant at the Bulgarian pilot site. This research will further investigate the environmental impacts such as the effects of biogas byproduct fertilizers on soil quality. It will also assess how pesticides influence biogas yields. Additionally, various biogas storage technologies, including biomethane and green oil, will be explored to optimize energy storage solutions. The outcomes will be integrated into a digital tool that supports local biogas producers and farmers in making informed decisions regarding biogas production from different feedstocks and understanding the soil health implications of biogas byproducts.
Actors included	• Plant owner (ALBENA) • Research institution (TRU) • Stakeholders (local biogas producers and farmers)
Triggering Event	The need to explore the biogas production potential of various organic wastes in the Dobrich district, as well as imported energy crops to develop a sustainable, economically and resource-optimized circular symbiosis.

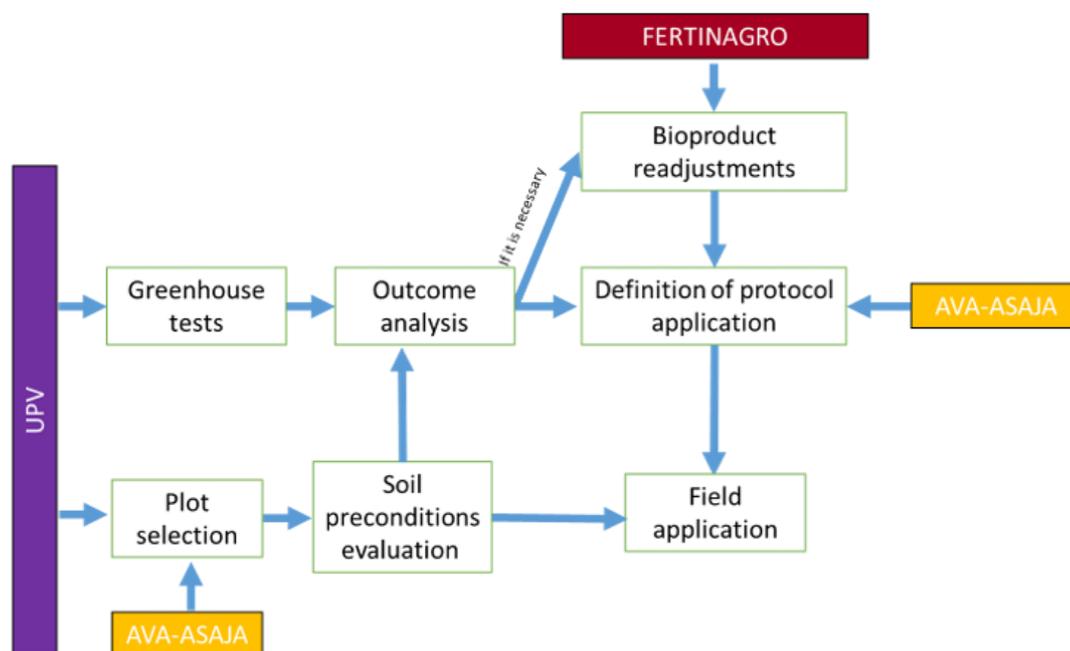| Related Use Cases | UC BG.01 Smart Agricultural PV Implementation in Greenhouses and scale-up in combination with Biogas energy for sustainable processes |
	UC BG.03 National and regional Regulation and business models' implementation to foster rural development
Related ECOLOOP Innovations	KER 1: Innovative and efficient biogas production and conversion process
	KER 4: Decision support tool for farmers and foresters
Pre-condition	• Identification of the feedstock that will be tested (agricultural residues and energy crops).
	• Establishment of conditions for a clear evaluation and comparison between the different types of feedstocks.
Post-condition	• The biogas production potential of the various types of organic waste and imported energy crops in the local area has been clearly determined
	• Exploration of different biogas storage technologies is completed. Integration of gathered data into a digital decision support tool for local biogas producers and farmers

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Identification of Feedstocks	Selection and sourcing of various organic wastes and potential energy crops to be tested for biogas production.	Detailed list and sources of organic waste available in the Dobrich district;	ALBENA	TRU
2	Laboratory Testing of Feedstocks	Conducting laboratory tests to analyse the biogas production potential and compatibility of mixed feedstocks.	Chemical composition, presence of pesticides, moisture content and calorific value of each raw material, dry and organic dry matter, gas production, methane and CO_2 content in biogas;	TRU	ALBENA
3	Scale evaluation	Analysis to determine the feasibility and requirements for scaling up biogas	Feasibility study results, including technological, economic, and logistical aspects of	TRU	ALBENA

		production using the tested feedstocks.	scaling production; projected biogas production volumes;		
4	Field Testing at Biogas Plant	Applying the laboratory findings to real-world biogas production at a pilot biogas power plant.	Real-world performance data of biogas yield from each feedstock; operational adjustments and optimizations; comparison of laboratory and field results.	ALBENA	TRU
5	Analysis of biogas byproducts	Evaluating the of biogas byproducts used as fertilizers on soil health and the impact of pesticide residues on biogas production efficiency;	Reports on soil health metrics pre- and post-application of biogas byproducts; impact assessments of pesticide residues on biogas production efficiency; overall environmental impact evaluations.	ALBENA	TRU
6	Technology Exploration for Biogas Storage	Exploring the possibility of storage technologies.	Cost-effective evaluations of whether storage technologies such as biomethane and green oil can be used	ALBENA	ALBENA
7	Integration into Digital Tool	Compiling all research data into a comprehensive digital decision support tool for local biogas producers and farmers.	Digital tool user manual; scenarios and predictive outcomes based on different feedstocks; guidelines for maximizing biogas production and optimizing soil health using biogas byproducts.	ALBENA, TRU	ECOLOOP partners developing KER 4.

Use Case sequence diagram

Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths.					

Realization

Main responsible partners (Author)	• ALBENA
Contributing partners	• TRU
Priority	High

UC BG.03	**National and regional regulation and business models' implementation to foster rural development**
Description	This UC focuses on advancing renewable energy adoption in agriculture by supporting small farming communities. Researchers from TRU will analyse national and EU regulations on RES, as well as economic and social factors influencing farmers' willingness to adopt renewable energy. The study will identify suitable technologies for cooperative models, allowing farmers to invest in community-owned renewable energy infrastructure. It will also explore business

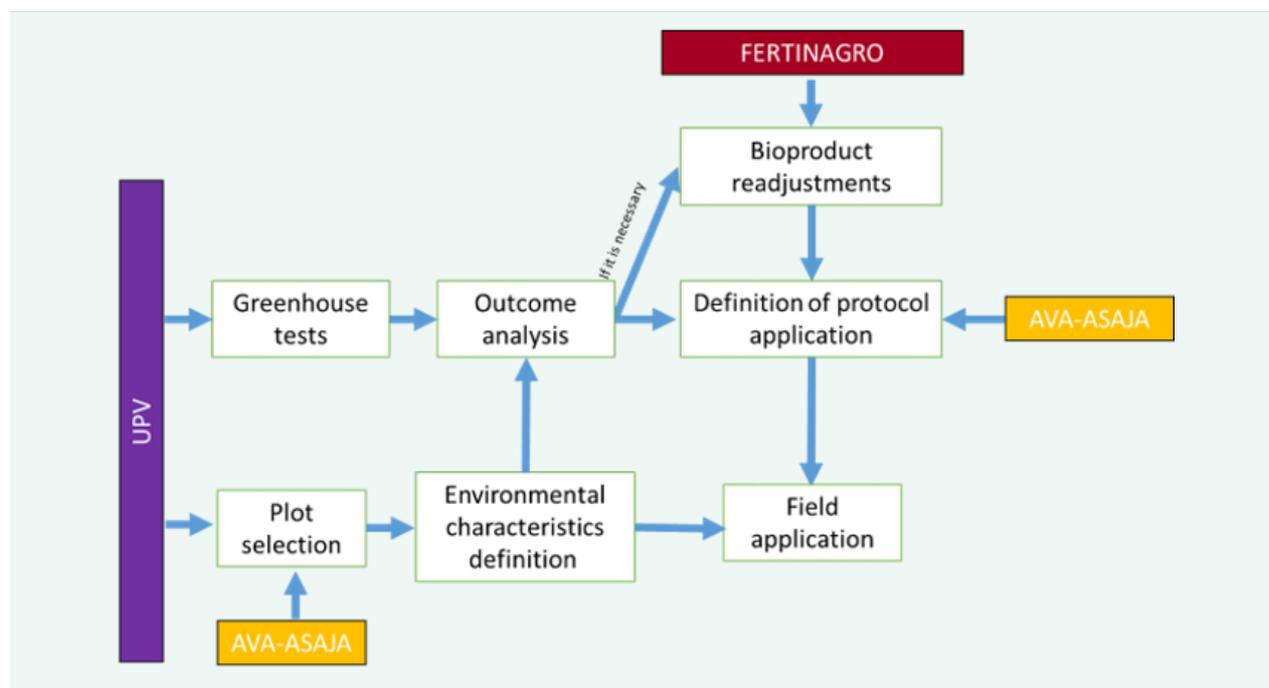|	
	frameworks that enable resource pooling and shared ownership. To boost participation, innovative subsidy models offering capital assistance and production-based incentives will be proposed, and consultations with farmers will help identify barriers to adoption. Additionally, unique branding will emphasise ecological sustainability and social cooperation, adding value to the communities involved. The UC aims to establish cooperatives that increase affordability and efficiency, while creating job opportunities and supporting shared infrastructure like heating and food processing systems. Collaboration with policymakers will help ensure favourable conditions and financial support, balancing public assistance with self-sufficiency in community energy programs.
Actors included	• Research institution (TRU) • Plant owner (ALBENA) • Decision makers • Local associations • End-users
Triggering Event	Promote energy self-sufficiency and independence for local farming communities through renewable energy solutions.
Related Use Cases	UC BG.02 Regional agricultural and other waste analysis and potential biogas production
Related ECOLOOP Innovations	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Pre-condition	• Results from the waste analysis and the potential for biogas production from UC BG.02 • Digital tool for local biogas producers and farmers for biogas predictions
Post-condition	Support schemes designed.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
I	Review and analysis of regulations and social/economic considerations	Comprehensively review current national, regional and European regulations related to renewable energy in agriculture. Analyse economic and social factors influencing farmer engagement. Identify gaps and barriers.	Reports detailing regulatory review, economic considerations, social dynamics and engagement barriers	TRU	TRU, local associations

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2	Explore modular technology and cooperative BMs	Research small-scale/modular biogas, biomass refinery and slow pyrolysis technologies suited for cooperation among local small farmer communities. Explore innovative cooperative business and subsidy models to incentivize engagement.	Technology reviews, business model proposals, subsidy model analyses	TRU	End-users Local associations
3	Community consultations and training	Host local workshops and seminars to consult farmers and agriculture associations on research findings and proposals. Provide training on circular solutions and cooperative models. Gather feedback.	Presentations, training manuals, feedback forms	TRU	End-users Local associations Decision makers
5	Facilitate the formation of multi-stakeholder energy cooperatives	Support the establishment of cooperative enterprises among farmers, agriculture associations and renewable energy experts based on created tools and solutions.	Cooperative registration documents, operating procedures, branding proposals	Cooperative participants	Cooperative participants
6	Consult policymakers on community models and support frameworks	Organize collaborative discussions between researchers, cooperatives, associations and policymakers to align on optimal community models, branding approaches and financial support frameworks.	Presentations, financial models, policy proposals, meeting minutes	TRU	End-users Local associations Decision makers

Use Case sequence diagram
No sequence diagram relevant for this UC.

Exception paths					
Step No.	**Event**	**Description of process / Activity**	**Info. exchanged**	**Actor producing the information**	**Actor receiving the information**

No exception paths.	
Realization	
Main responsible partners (Author)	• TRU
Contributing partners	• ALBENA
Priority	High

8.3. EE pilot

UC EE.01	**Wood ash recycling system for forest plantations**
Description	The primary objective of this UC is the recycling of nutrient-rich wood ash to stimulate tree growth.
	Wood ash is a waste from heating systems when woody biomass is used to produce energy. However, wood ash contains macro- and micronutrients that can support tree growth. The pilot sites of wood ash fertilization will be studied to develop the recycling of wood ash back to forest plantations.
	The main outcomes of the UC are: the development of wood ash recycling to forest plantations for smart usage of energy waste from heating system with woody biomass, the potential impact of wood ash to woody biomass modelling for forest plantations.
	In addition, the effect of wood ash on biodiversity and the environment, such as nutrient leaching, will be assessed. The business model and carbon footprint model will be developed considering all operations of the nutrient-rich ash recycling in forest plantations.
Actors included	• Research institution (EULS) • Forest management companies (RMK, Foreko) • End-users • Decision makers
Triggering Event	• The rising amount of nutrient-rich wood ash from heating systems when woody biomass is used to produce energy
Related Use Cases	UC EE.02 Carbon calculator for forest plantations UC EE.03 New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations UC EE.04 The potential wood production of different deciduous tree species on different soil types
Related ECOLOOP Innovations	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater KER 4: Decision support tool for farmers and foresters

	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols				
Pre-condition	• Nutrient-rich wood ash • Cut-away peatlands for reforestation				
Post-condition	• Recycling of wood ash • Stimulated yield production of forestry plantations on organic soils, such as cut-away peatlands				

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Data collection from wood ash experiment areas (cut-away peatlands)	Monitoring of deciduous plantation production	Measurement of plantation production	EULS	EULS
2	Data analysis	Statistical data analyses, development of growth and yield models	Growth and yield tables of plantations	EULS	EULS
3	The carbon sequestration calculation for forest plantations	Data collection and analysis to evaluate carbon fixed in plantations and developed into a carbon calculator	Improved growth by using wood ash; option to model carbon with or without wood ash in carbon calculator	EULS	End-users Forest management companies Decision makers Public
Use Case sequence diagram					

Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths					

Realization

Main responsible partners (Author)	Add one or maximum two partners from this list:
	• EULS
Contributing partners	No contributing partners.
Priority	High

UC EE.02   Carbon calculator for forest plantations

Description	The primary objective of this UC is the development of a carbon sequestration tool/calculator for forest plantations. The datasets of the scenarios and cases from the pilot sites will be the basis for developing a unique carbon sequestration calculator. The carbon calculator considers all variables (e.g., tree species, soil type, fertilization etc.) and estimates the amount of CO_2 stored in forest plantation, the potential profit from CO_2 credit and estimates the climate benefit from substitution effect, i.e. avoided CO_2 release from fossil energy and materials. The tool will be applicable for private landowners and

	forest companies and will have free access as a web platform. Decision makers, politicians and non-government organizations can use the tool to estimate the substitution effect of replacing fossil energy sources with renewables. Outcome: Carbon calculator for landowners and companies to estimate the potential profit from CO_2 fixation in marginal lands from wood production and carbon credit.
Actors included	• Research institution (EULS) • Forestry industry (FIB) • Forest management company (Foreko) • End-users • Decision makers
Triggering Event	• End users' intention to establish forest plantation on marginal land
Related Use Cases	UC EE.01 Wood ash recycling system for forest plantations UC EE.03 New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations UC EE.04 The potential wood production of different deciduous tree species on different soil types
Related ECOLOOP Innovations	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Pre-condition	• The datasets of the scenarios and cases from the pilot sites
Post-condition	• Carbon calculator for landowners and companies

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Data collection	Measurement of tree growth characteristics in forest plantations of different tree species and site types	Datasets with plantations basic tree growth characteristics (i.e. tree height, diameter, basal area, wood volume)	EULS	EULS FIB
2	Data analysis	Statistical data analyses, development of	Growth and yield tables of plantations; wood assortments (logs, pulp and energy)	EULS FIB	EULS

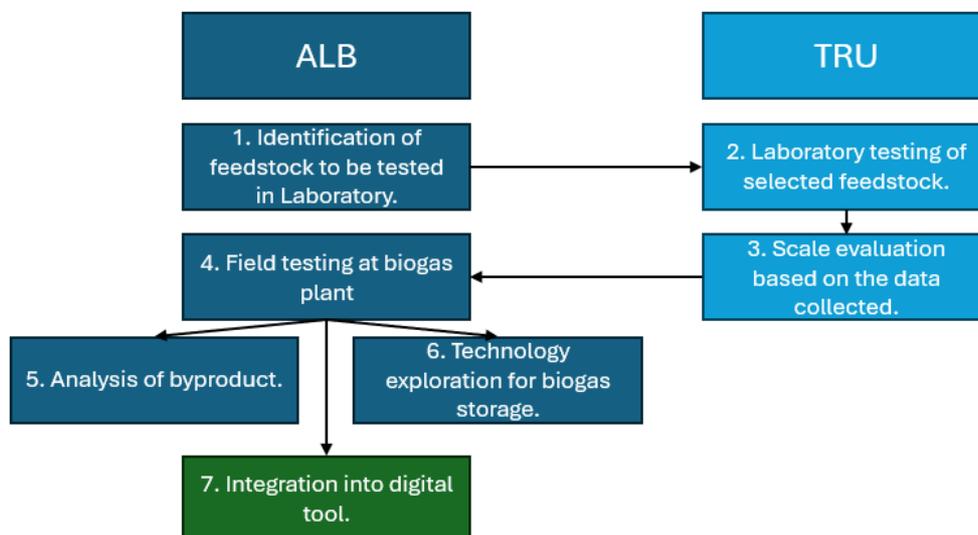|					
		growth and yield models			
3	Development of carbon sequestration calculator for forest plantations Testing of demo version/addressing the issues	The data gathered during steps one and two will be used to evaluate carbon stored in plantations and developed into a carbon calculator	/	EULS	EULS
4.	Introducing the final online version of carbon calculator	Demo version introduction (for Estonian conditions), user test group (includes companies) and their feedback	Feedback from all ECOLOOP partners	All ECOLOOP partners EULS	EULS All ECOLOOP partners Foreko
5.	Carbon calculator launch	Carbon calculator is launched and working online	/	EULS	End-user Landowner Decision makers
Use Case sequence diagram					

Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths.					

Realization

Main responsible partners (Author)	Add one or maximum two partners from this list:
	• EULS
Contributing partners	• FIB
	• Foreko
Priority	High

UC EE.03 New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations

Description	The primary objective of this UC is to research the effect of biostimulants on the production of forest plantations and work out certification systems for legalized fertilization.
	Fertilization of forestland is not allowed according to the current regulations. Recently, a new biostimulant based on organic nitrogen (arGrow) came to the market to improve trees' early growth in conventional forestry but the effect of "*arGrow*" on deciduous forest plantations is unknown. The established experiments of "*arGrow*" biostimulant in combination with mineral fertilizers in the pilot areas will be assessed to see the potential to improve tree growth. The potential production increase from the new biostimulant and mineral fertilizers will be modelled for forest plantations. In addition, the effect of fertilization on biodiversity and the environment (such as nutrient leaching) will be assessed. The results can be implemented to certification systems of forest plantations to legalized fertilization as a sustainable approach to produce more renewables in the region.
Actors included	• Research institution (EULS) • Forestry management companies (Foreko) • Decision makers • End-users
Triggering Event	• Landowners' intention to improve tree growth during the establishment phase
Related Use Cases	UC EE.01 Wood ash recycling system for forest plantations UC EE.02 Carbon calculator for forest plantations

	UC EE.04 The potential wood production of different deciduous tree species on different soil types
Related ECOLOOP Innovations	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Pre-condition	• The datasets of the scenarios and cases from the pilot sites
Post-condition	• Stimulated production of deciduous forest plantations

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	The establishment of "*arGrow*" biostimulant experiments in combination with mineral fertilizers on the pilot areas	Monitoring of deciduous plantation production	Measurement of plantation production	EULS	EULS
2	Data collection	Measurement of tree growth characteristics in forest plantations	Datasets with plantations basic tree growth characteristics	EULS	EULS
3	Data analysis	Statistical data analyses, development of growth and yield models	Growth and yield tables of plantations	EULS	EULS Public Decision makers
4	The carbon sequestration calculation for forest plantations	Data collection and analysis to evaluate carbon fixed in plantations and developed into a	Improved growth by using biostimulant; option to model carbon with or without biostimulant in carbon calculator	EULS	End-users Landowners Decision makers Public

		carbon calculator			

Use Case sequence diagram

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information

No exception paths

Realization	
Main responsible partners (Author)	Add one or maximum two partners from this list:
	• EULS
Contributing partners	• Foreko
Priority	High

UC EE.04	The potential wood production of different deciduous tree species on different soil types
Description	The potential production of forest plantations is unknown in a full rotation cycle in Estonian conditions under different soil types as the soil variation can significantly affect the performance of trees. A diverse range of tree species on 70 soil types will be monitored and their potential yield modelled throughout the entire rotation cycle. The classification of Estonian soil types will be obtained from the soil maps. Afforestation scenarios of different land areas (maximum, medium and minimum potential available area) for forest plantations will be evaluated. The modelled production estimates from the pilot sites of different tree species on various soil types will be implemented all over Estonia, in general. The potential of forest plantations for woody biomass production in Estonia will be evaluated according to the scenarios of the afforestation area (maximum, medium and minimum).
Actors included	• Research institution (EULS) • Forestry industry (Foreko) • End-users • Decision makers • Public
Triggering Event	• The potential of deciduous forest plantations depending on soil type
Related Use Cases	UC EE.01 Wood ash recycling system for forest plantations UC EE.02 Carbon calculator for forest plantations UC EE.03 New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations
Related ECOLOOP Innovations	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Pre-condition	• The datasets of the scenarios and cases from the pilot sites
Post-condition	• The potential of forest plantations for woody biomass production in Estonia

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Afforestation scenarios of different land areas	Analysis of data collected from pilot sites	Datasets with deciduous plantations' basic tree growth characteristics	EULS Foreko	EULS

2	Potential yield modelling	Analysis of yield data collected from deciduous plantations	Datasets with deciduous plantations' total production and different wood assortments	EULS	End-users Decision makers Public Landowners
3.	The carbon sequestration calculation for forest plantations	Preparation of datasets created in step 2 for the estimation of carbon fixed in plantations	Input data for the carbon calculator development	EULS	End-users Decision makers Public Landowners

Use Case sequence diagram

Exception paths					
Step No.	**Event**	**Description of process / Activity**	**Info. exchanged**	**Actor producing the information**	**Actor receiving the information**
No exception paths					

Realization	
Main responsible partners (Author)	Add one or maximum two partners from this list:
	• EULS
Contributing partners	• Foreko
Priority	High

8.4. SI pilot

UC SI.01	Optimize the operation and improve the security of the supply of biomass centre Nazarje
Description	This UC will concentrate on the development of the technical and market optimization model of the entire local energy system (heat & power) of the Biomass centre Nazarje.
	The model will be used to simulate and emulate various aspects of cross-function planning and utilize the resulting market opportunities optimally to evaluate different energy strategies (e.g., TOTEX minimization, RES production maximization, CO_2 emission minimization, etc.). The model will show its dynamic behaviour under different operating conditions, simulating different performance scenarios of the deployed assets. The model will enable the optimization of the operation in the Biomass centre Nazarje based on the operational scenario and security, technical and economic boundaries defined by the customer. It will also improve the security of supply, as assets could be used in a way to ensure self-sufficiency and thus independence of the electricity network.
	This UC will also consider offering an excess of the locally generated heat to end-users in the industrial zone and will thus improve the environmental and social aspects of energy supply for the local community.
	This UC also includes conceptual design, development and installation of a solar PV power plant, and the inclusion of e-mobility infrastructure and BESS, which will allow for further optimization of energy demand and generation matching to provide technical, economic, environmental and social benefits to the entire industrial zone of Biomass centre Nazarje.
Actors included	• Aggregator • Research institution • Biomass producer/ Asset owner
Triggering Event	Setting/determination of the operational scenario (e.g., TOTEX minimization).

Related Use Cases	UC SI.02 Utilization of flexibility of the biomass centre Nazarje
Related ECOLOOP Innovations	KER 1.1: Flexibility management to increase the profitability of the slow pyrolysis process KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Pre-condition	• Assets are integrated with the aggregator's platform. • Measurement data from assets is provided.
Post-condition	Optimal schedules for individual energy assets are calculated based on the determined operational scenario.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Operational scenario determination	The assets owner determines the operational scenario.	Security, technical, and economic boundaries Optimization goal (e.g., TOTEX minimization, €/MWh must be < 100 €)	Assets owner	Aggregator
2	Data collection	The aggregator collects measurement, availability and constraints data from the assets.	P measurement (MW) Availability (schedule) Constraints	Flexibility assets	Aggregator
3	Technical and Market Optimization Calculation	The aggregator performs technical and market optimization calculations.	/	Aggregator	Aggregator
4	Operating schedules determination	Based on the technical-market optimization calculation the operating schedules for the assets are determined.	Set points and schedules for flexibility assets.	Aggregator	Aggregator

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| 5 | Schedules forwarding | The calculated schedules are distributed to the asset owner. | Set points and schedules for flexibility assets. | Aggregator | Asset owner |

Use Case sequence diagram

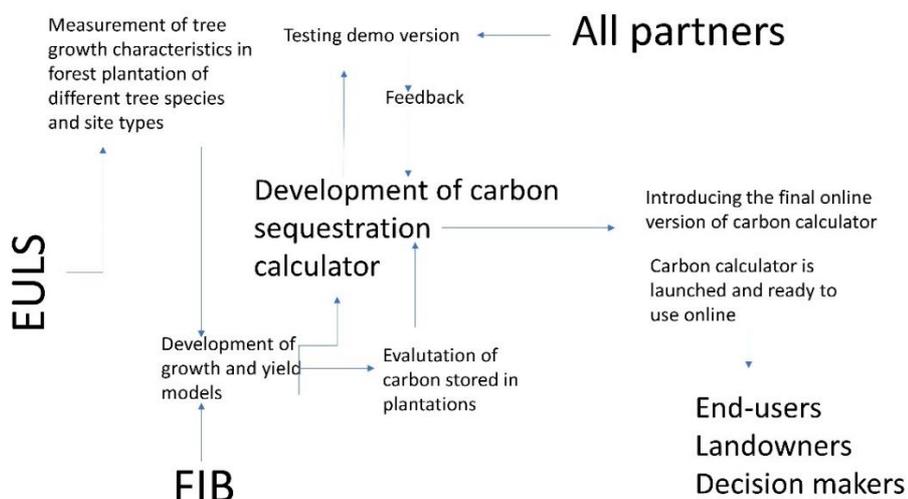| Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
2a	Data collection not successful.	If the data cannot be collected or is insufficient, the optimization algorithm cannot run.	/	Asset owner	Aggregator

Realization

Main responsible partners (Author)	• SETUP

Contributing partners	- BIOM - UL
Priority	High

UC SI.02	Utilization of flexibility of the biomass centre Nazarje
Description	The primary objective of this UC is to utilize the flexibility of the Biomass centre (12 existing CHP units, 2 installed CHP units within the scope of the project, BESS, charging station/s for EV) for providing ancillary services to the system operator, TSO and potentially DSO. This will in turn offer passive monetization to Biomass centre and additionally, provide strategic benefits to the power grid as flexibility assets can help with the stability of the power system and consequently unlock the deployment of more renewables in the system. In the scope of the UC, the flexibility assets of the biomass centre Nazarje will be connected to the Kolektor sETup aggregator platform. Based on the historical measurements, availability and security, technical and economic boundaries, the aggregator will develop a model for baseline and flexibility forecast. Based on the forecast calculation, the aggregator will place (capacity and energy) bids in the ancillary services markets of TSO and potentially DSO. If at any moment in time, the (energy) bid is accepted, the algorithm, which will be integrated with the aggregation platform, could perform an optimal selection of available flexibility from the pool of Biomass centre Nazarje's flexibility assets, based on the amount of energy/power needed and the energy price. The utilization of flexibility has a crucial role in the stabilization of the frequency in the transmission system power network, while also having several positive influences on the local power networks (stabilization of voltage, help with overutilization). Consequently, the utilization of flexibility unlocks the deployment of more RES in the grid.
Actors included	- Aggregator - TSO - Market operator - Research institution - Biomass producer/ Asset owner
Triggering Event	Market Auction (e.g., TSO ancillary services market auction).
Related Use Cases	UC SI.01 Optimize the operation and improve the security of supply of biomass centre Nazarje
Related ECOLOOP Innovations	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Pre-condition	- Assets are integrated with the aggregator's platform. - Availability and security, technical and economic boundaries from asset owner are provided. - Measurement data from assets is provided.

Post-condition	• Flexibility bid (capacity or energy) is placed. • Flexibility assets are activated.				

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Market auction	Market operator (TSO or DSO) publishes ancillary services market auction.	Conditions for bidding are published.	Market operator	Interested parties (aggregators)
2	Data collection	The aggregator collects measurement, availability and constraints data from the assets.	P measurement (MW) Availability (schedule) Constraints	Flexibility assets	Aggregator
3	Aggregation of the flexibility	Based on the measurement, availability and constraints data from the assets, the baseline, flexibility and price are calculated/defined.	Baseline (MW) Flexibility +/- (MW) Flexibility price (€/MW/h)	Aggregator	Aggregator
4	Bid is placed	The aggregator gathers the measurement data from energy assets and calculates the baseline and flexibility.	Bidding power (MW) Price for energy unit (€/MW/h)	Aggregator	Market operator
5	Bid is accepted	The market operator accepts the bid and sends a signal for activation.	Activated power in MW, direction (- or +).	Market operator	Aggregator

6	Input data from assets is received	The aggregator receives input data from the assets.	P measurement (MW) Calculated: Baseline Flexibility +/- Maximal duration of flexibility Price for Flexibility	Flexibility assets	Aggregator
7	Optimization module for selecting the optimal available flexibility	The aggregator runs the optimization module for selecting the optimal available flexibility based on the data from the system operator and input data from assets.	Optimal list of devices to be activated	Aggregator	Aggregator
8	Assets are activated	The aggregator activates the most optimal assets.	Activation setpoint (power)	Aggregator	Flexibility assets

Use Case sequence diagram

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
2a	Data collection not successful.	If the data cannot be collected or is insufficient, the aggregation calculation and bid placement cannot be performed.	/	Asset owner	Aggregator
5a	Bid is rejected	The market operator rejects the bid.	Information about the rejection	Market operator	Aggregator
6a	Input data from assets is not received.	If the data cannot be collected or is insufficient, the optimization module calculation and	/	Asset owner	Aggregator

		asset activation cannot be performed.			
8a	Activation of assets not successful.	If the activation of assets is not successful, the penalties have to be paid.	/	Aggregator	Aggregator/ Flexibility assets

Realization

Main responsible partners (Author)	• SETUP
Contributing partners	• UL • BIOM
Priority	High

UC SI.03	Design of a modular biomass slow pyrolysis system solution
Description	The primary objective of the UC is the concept and design of the prototype of a modular version of the woody biomass power plant. The cascade building of the BIOM CHP power plant in the Slovenian pilot utilizes modularity of the overall system in reaching desired installed power and accompanying woody biomass storage facilities. Based on the potential buyer's requirements and needs, a tailored solution can be designed by cascading the individual units and allocating proper storage capacity for the woody biomass. The main outcome of the UC will be the design of a small, container-based CHP unit, suitable for smaller sawmills, farms or other stakeholders with biomass materials. The container unit design with basic specifications of the CHP units and required storage space will be investigated. The breakdown of the operational costs and revenues will be investigated together with the concept to provide sufficient information to the potential customers on the modular unit and its potential for scaling up the system with multiple container housing. A prototype of the container unit will be prepared in the Biomass centre, with an installed CHP unit of 50 kW and a drying chamber for the woody biomass as the basic smallest container unit available, with the possibility of upgrading or expanding the system to the desired proportions to meet the required electric and thermal needs of the customer.
Actors included	• Aggregator • Research institution • Modular CHP power plant provider
Triggering Event	• Demand for small scale CHP units for potential customers • Order/purchase/expansion of the CHP system from the customer
Related Use Cases	UC SI.01 Optimize the operation and improve the security of supply of biomass centre Nazarje

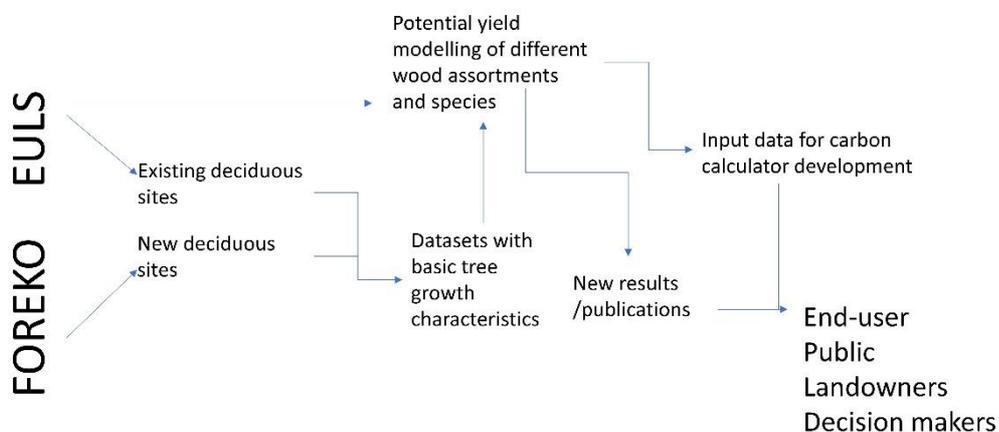|	UC SI.02 Utilization of flexibility of the biomass centre Nazarje
	UC SI.04 Biochar maximum utilization
Related ECOLOOP Innovations	KER 1.1: Flexibility management to increase the profitability of the slow pyrolysis process
	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Pre-condition	• Specifications and dimensions of individual components of the CHP (the unit, drying chamber, storage unit etc) • Available container variants, suitable for CHP system implementation • Demand-based or predefined CHP system specification
Post-condition	• Optimal CHP container module is designed for the customer's requirements • Several variants of the container design are available for the market • The container is designed to present the modular concept or for commercial orders if present

Basic paths

Step No.	Event	Description of process / activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Product specification	Based on required customer specifications or predefined specs the initial system configuration is defined	CHP unit required power, CHP dimensions and required woody biomass storage space	Modular CHP power plant provider	Research institution Aggregator
2	Design of the production container	Based on selected assets, the CHP placement in the container is prepared	Container dimensions and CHP plan installation	Modular CHP power plant provider	Modular CHP power plant provider
3	Design of the storage and drying chambers	Additional storage and drying chambers are prepared to meet required woody biomass capacity	Storage and drying chambers dimensions and plan installation	Modular CHP power plant provider	Modular CHP power plant provider
4	Cost breakdown and revenue calculation	An economic evaluation of designed business	Cost of the components, market prices of electricity, subsidies, prepared information for end user	Research institution	Modular CHP power plant provider Aggregator

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5	Full system design information	Fitting the CHP and storage components into overall unit configuration		Modular CHP power plant provider	Modular CHP power plant provider
6	Production plan for the designed CHP	Detailed plan/schemes for the designed unit	Dimensions, part list and system specifications	Modular CHP power plant provider Research institution	Modular CHP power plant provider
7	Realized modular CHP container	Installation of the CHP into the container module, preparation of the drying and storage compartment	/	Modular CHP power plant provider	Modular CHP power plant provider

Use Case sequence diagram
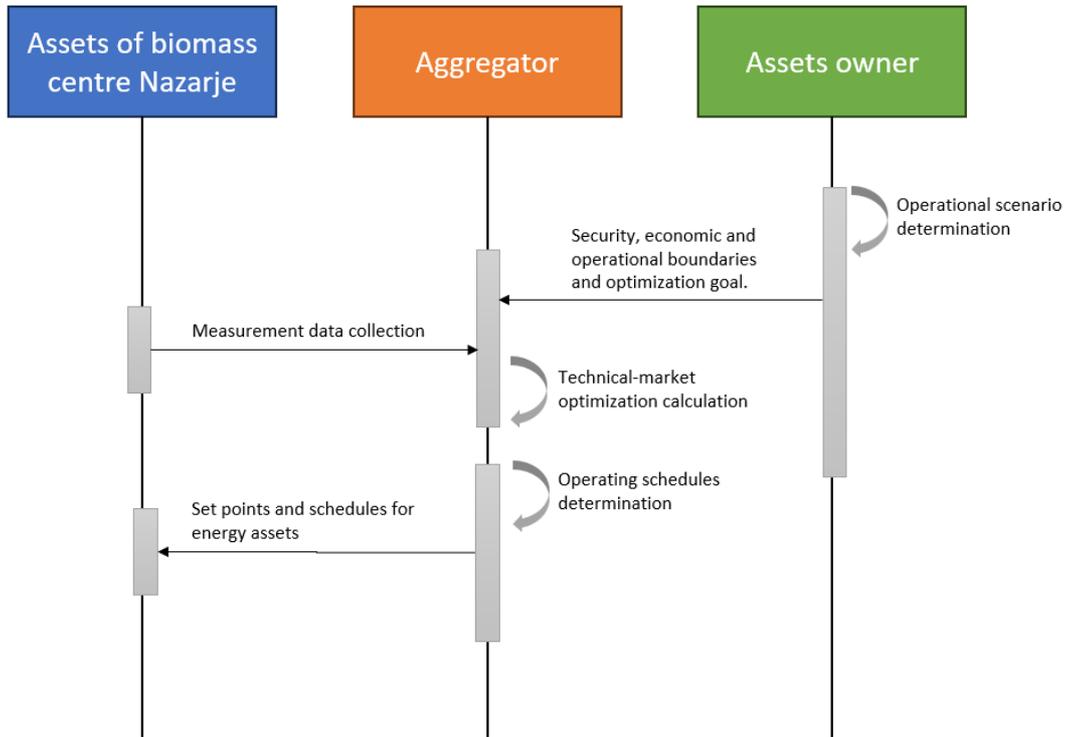
Exception paths					
Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
No exception paths.					

Realization

Main responsible partners (Author)	• BIOM
Contributing partners	• UL • SETUP
Priority	High. The modular design of the CHP power plant will increase the potential of the CHP utilization with the small-scale units, which are suitable for many locations and business cases, which will inherently provide BIOM new business opportunities.

UC SI.04	Biochar maximum utilization
Description	In CHP operations, biochar is produced as a byproduct of the wood pyrolysis process. The temperature of the biomass burner, which produces gas and burning residues such as char and ashes, determines the process's efficiency, power output, and the amount of byproducts. While high temperatures result in higher power output from CHPs, lower temperatures result in lower power output and biochar production as opposed to ashen residues in a high-temperature cycle. Biochar production will be investigated in this pilot's UC. One of the pilot's production units, and every aspect of its operation, will be used for biochar research. The woody biomass burner, which generates gas for CHP operation has a temperature range for its operation. The lowest and highest possible temperature setpoints of operation will be identified and the number of temperature setpoints will be defined for scenario analysis of CHP operation. For each scenario, a multilevel analysis will be performed. The correlation between temperatures and electric and thermal power output of the CHP will be determined as well as the amount of Biochar and ashen residues. The quality of the biochar side products will be chemically analysed to define the quality of the biochar and its suitability for use. The analysis will highlight the biochar attributes and its suitability as a bio-grade fertilizer for use in agriculture (farming fields, greenhouses) and as an additive for slurry fertilizing of agricultural surfaces. The chemical structure of the biochar will also determine its suitability for animal husbandry, as biochar is a known additive for improved feed, used for cattle, sheep, and chicken.

	After the CHP production rates comparison and chemical analysis of biochar products, an economic evaluation will be performed. The biochar side product value will be implemented in overall CHP cost and revenue streams to determine its impact on the profitability of CHP operation.
Actors included	• Agricultural institute of Slovenia • Aggregator • Research institution • Biomass producer/ Asset owner
Triggering Event	• Variable temperature setpoint operation of CHP • Lower temperature range of operation provides biochar production
Related Use Cases	UC SI.01 Optimize the operation and improve the security of supply of biomass centre Nazarje UC SI.02 Utilization of flexibility of the biomass centre Nazarje UC SI.03 Design of a modular biomass slow pyrolysis system solution
Related ECOLOOP Innovations	KER 1.1: Flexibility management to increase the profitability of the slow pyrolysis process KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Pre-condition	This UC requires a CHP unit, where the gasifier's operational temperature for burning woody biomass will be varied to analyse the quality of the produced biochar. A quality woody biomass must be prepared in advance in sufficient amounts to provide similar benchmark conditions for evaluation of biochar quality in different scenarios
Post-condition	After the UC, the CHP distributor will have an insight into the potential (yield) of the biochar production of the CHPs, its chemical structure and suitability for use in agricultural purposes, which presents an additional revenue stream in CHP operation.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Biomass preparation	Sufficient biomass fuel for the analysis must be allocated	Amount of Biomass available for the test trials	Biomass producer/ Asset owner	Research institution Agricultural institute of Slovenia
2	CHP operational setpoints definition	The lowest and highest temperature setpoints will be identified with several setpoints within the range	Operational scenarios	Biomass producer/ Asset owner Research institution Aggregator	Biomass producer/ Asset owner

3	CHP operation in defined scenarios	CHP operation (power and side product yield) will be evaluated and monitored	CHP power output and biochar/ashes yield will be investigated	Biomass producer/ Asset owner	Research institution Agricultural institute of Slovenia Aggregator
4	Biochar analysis	Produced biochar in individual scenarios will be examined	Amount and chemical structure of biochar products will be compared	Agricultural institute of Slovenia Biomass producer/ Asset owner	Research institution
5	Economic evaluation	Electricity and heat production, provision of flexibility and biochar production will be evaluated for individual scenarios to identify economic aspects of various CHP operation modes	Operational parameters, biochar quantity and quality, electricity market results (flexibility)	Biomass producer/ Asset owner Agricultural institute of Slovenia Aggregator	Research institution
6	Integration of biochar production process	The benefits/revenues of biochar production will be integrated into CHP operation to improve its revenue streams	The potential use of biochar and its values is integrated into CHP's business model	Biomass producer/ Asset owner Research institution Aggregator	Biomass producer/ Asset owner

Use Case sequence diagram

Exception paths

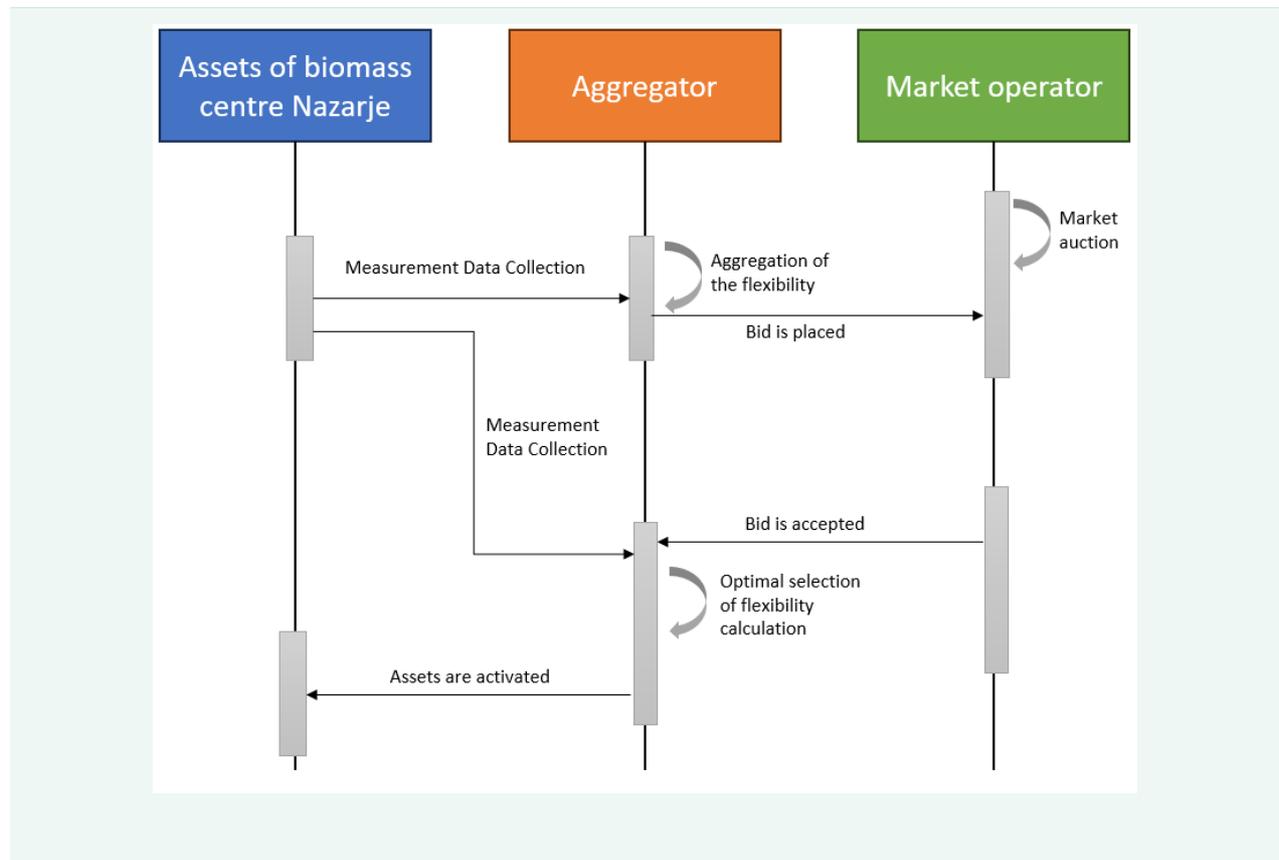| Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information

No exception paths.

Realization	
Main responsible partners (Author)	• BIOM
Contributing partners	• UL • KIS • SETUP
Priority	High. As biochar production presents an efficient carbon capture measure, biograde fertilizer and soil enhancer, its potential for agriculture and livestock purposes will be further investigated in this UC which will improve the CHP business case as it goes hand

in hand with flexibility provision in form of step-down activation of the production units.

UC SI.05	Biomethane from biogas power plant utilization for agricultural machinery
Description	KIS has a micro biogas plant for wet anaerobic processes to produce biogas, which is used on CHP unit for producing electrical and thermal energy. This energy is used on the farm of KIS as follows: surplus electricity can be sent to the public electricity grids, and excess heat can be used on the farm. The electric power unit on CHP is 7 kWe. The micro biogas plant has 1 – digester, 2 – energetic containers with units for processing of input substrate, cleaning of biogas, biogas powered cogeneration (electrical and thermal energy production), thermal energy storage and electronic regulation of process of biogas production, 3 – biogas holder integrated in container for mechanical protection, 4 – dosing system for adding solid biomass connected with milling unit for mechanical pre-processing of solid biomass with milling. The micro biogas plant facilitates the eco-friendly conversion of various organic wastes, like liquid manure and seed production by-products, into biogas, mitigating greenhouse gas emissions and odours. This biogas not only reduces the farm's energy dependency and emissions but also serves as organic fertilizer post-digestion. Currently, KIS is in the initial stages of producing biomethane from biogas, focusing on preparing subsystems for a modular biomethane plant where biogas will be purified and upgraded to methane. Biomethane serves as a versatile fuel for tractors and machinery, compatible with both methane and dual-fuel engines (using diesel and methane). Beyond energy production, the biomethane plant generates digestate, a high-quality organic fertilizer, enhancing sustainability in agricultural practices.
Actors included	• Agricultural institute of Slovenia (KIS) • Research institution (IRI UL) • Biogas/biomethane technology providers • Producers of agricultural machinery • Farmers association • Decision makers
Triggering Event	The development and integration of biomethane capture technologies into the operational framework of the biogas power plant at KIS.
Related Use Cases	UC SI.06 Redesign of subsidies and new business models for modular biogas
Related ECOLOOP Innovations	KER 1: Innovative and efficient biogas production and conversion process KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes

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Pre-condition	Availability of a functional biogas power plant, preparation for biomethane production technology and necessary infrastructure for farm machines operation.
Post-condition	Establishment of a sustainable, eco-friendly fuel alternative for farm machines (tractors, self-propelled machines) along with a strategic action plan for its integration and future development within the Slovenian agricultural sector.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
1	Technology integration	Integration of biomethane processing technology into the existing biogas modular plant.	Integration reports with technical data	KIS Biogas/biomethane technology providers	KIS
2	Biomethane production and use	Cleaning and upgrading biogas to biomethane and installing dispensing units for filling farm tractors and working machines with biomethane.	Biomethane pilot production and data, analysis of biomethane (physical and chemical characteristics, etc.) Safety procedures for filing reservoirs of farm tractors and self-propelled machines with biomethane	KIS Biogas/biomethane technology providers	KIS Biogas/biomethane technology providers Producers of agricultural machinery
3	Use of biomethane on farm machines	Operational testing on using biomethane on farm machines (tractor) in some agricultural working operations	Operational test results, biomethane consumption, efficiency, reliability, safety of use and other performance data	KIS Biogas/biomethane technology providers	KIS Biogas/biomethane technology providers Farmers association Decision makers

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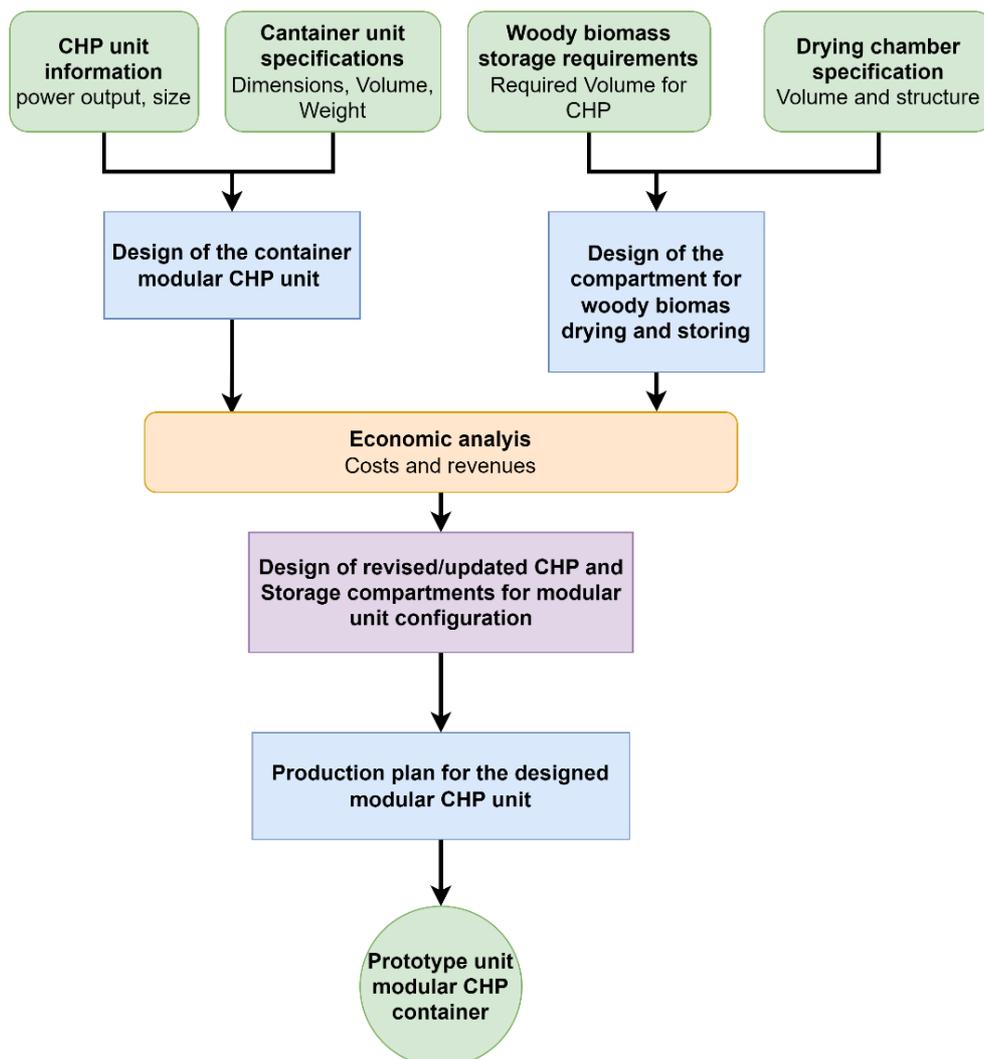|					
		with low, medium and high loads.			
4	Feasibility and impact analysis	Analyzing the feasibility, efficiency, and environmental impact of biomethane production and use on farm machines (tractor).	Analysis reports, environmental data, Comparison of the carbon footprint of biomethane production and use of biomethane on farm machines (tractor) in real operational conditions with the carbon footprint of conventional farm machines (tractor operating on mineral diesel fuel)	KIS Biogas/biomethane technology providers	KIS Farmers association Decision makers
5	Strategic Action Plan Development	Developing a strategic plan for future integration and development of biomethane production and use it for farm machines and municipal (tractors and self-propelled machines).	Strategic plan, implementation roadmap	KIS	KIS Farmers association Decision makers
Use Case sequence diagram					

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1a	Technology adaptation challenges	Addressing challenges in adapting biomethane production technologies and the use of biomethane for farm machines.	Challenge reports, adaptation strategies	Agricultural institute of Slovenia Biogas/biomethane technology providers	Agricultural institute of Slovenia External consultants
1b	Environmental Impact Concerns	Addressing environmental impact concerns during technology integration	Environmental concern reports, mitigation plans	KIS	KIS management, Regulatory bodies, Ministry of Environment, space and energy,

Realization

Main responsible partners (Author)	• KIS
Contributing partners	• UL
Priority	High

UC SI.06	Redesign of subsidies and new business models for modular biogas
Description	This UC aims to revolutionize the agricultural sector's energy landscape by pioneering new BMs and revamping subsidy schemes for biogas and biomethane production. This initiative is part of a broader strategic effort to promote renewable energy in rural areas, aligning with the sustainable development goals and circular economy principles. By focusing on the development and integration of biomethane, the project seeks to reduce the carbon footprint in agricultural practices, enhance energy self-sufficiency, and foster economic growth in rural communities. This endeavour involves a comprehensive approach, including the exploration of innovative financial support mechanisms, policy amendments, and community-centric models, particularly targeting biogas plants. The overarching objective is to create a replicable and scalable framework that can be adopted widely, leading to a transformative impact on renewable energy usage in agriculture and rural development.
Actors included	• Research institution (IRI UL) • Agricultural institute of Slovenia (KIS) • End-users • Farmers association • Decision makers
Triggering Event	The need to enhance renewable energy usage in rural areas, reduce carbon footprint in agricultural practices, and foster sustainable development in the agriculture sector.
Related Use Cases	UC SI.02 Utilization of flexibility of the biomass centre Nazarje UC SI.05 Biomethane from biogas power plant utilization for agricultural machinery
Related ECOLOOP Innovations	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Pre-condition	• Research on existing subsidies and BMs
Post-condition	• Implementation of new BMs and subsidy structures promoting biogas and biomethane production. • Enhanced sustainable agricultural practices with reduced carbon footprint and increased energy self-sufficiency.

Basic paths

Step No.	Event	Description of process /activity	Info. exchanged	Actor(s) producing the information	Actor(s) receiving the information
I	Assessment of current biogas production	Review the current state of biogas production at KIS and country, identifying opportunities for	Plant status report, opportunity analysis	KIS	KIS

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information
		improvement and integration into new BMs			
2	Development of new BMs	Collaboratively create innovative BMs that cover the needs of the rural energy sector, focusing on biogas and biomethane production and use of both energy sources for agricultural production	Business model drafts, feasibility studies	KIS IRI UL	KIS Decision makers
3	Policy and Subsidy Redesign	Collaboration with stakeholders to propose and advocate for policy changes and redesigned subsidies that support the new BMs for biogas and biomethane production and use of both energy sources for agricultural production	Policy proposals, subsidy redesign plans	KIS IRI UL	KIS Decision makers
4	Implementation and monitoring	Implement the new BMs and monitor their performance, making adjustments as necessary to ensure their effectiveness and sustainability	Implementation reports, performance data	KIS	KIS Decision makers

Use Case sequence diagram

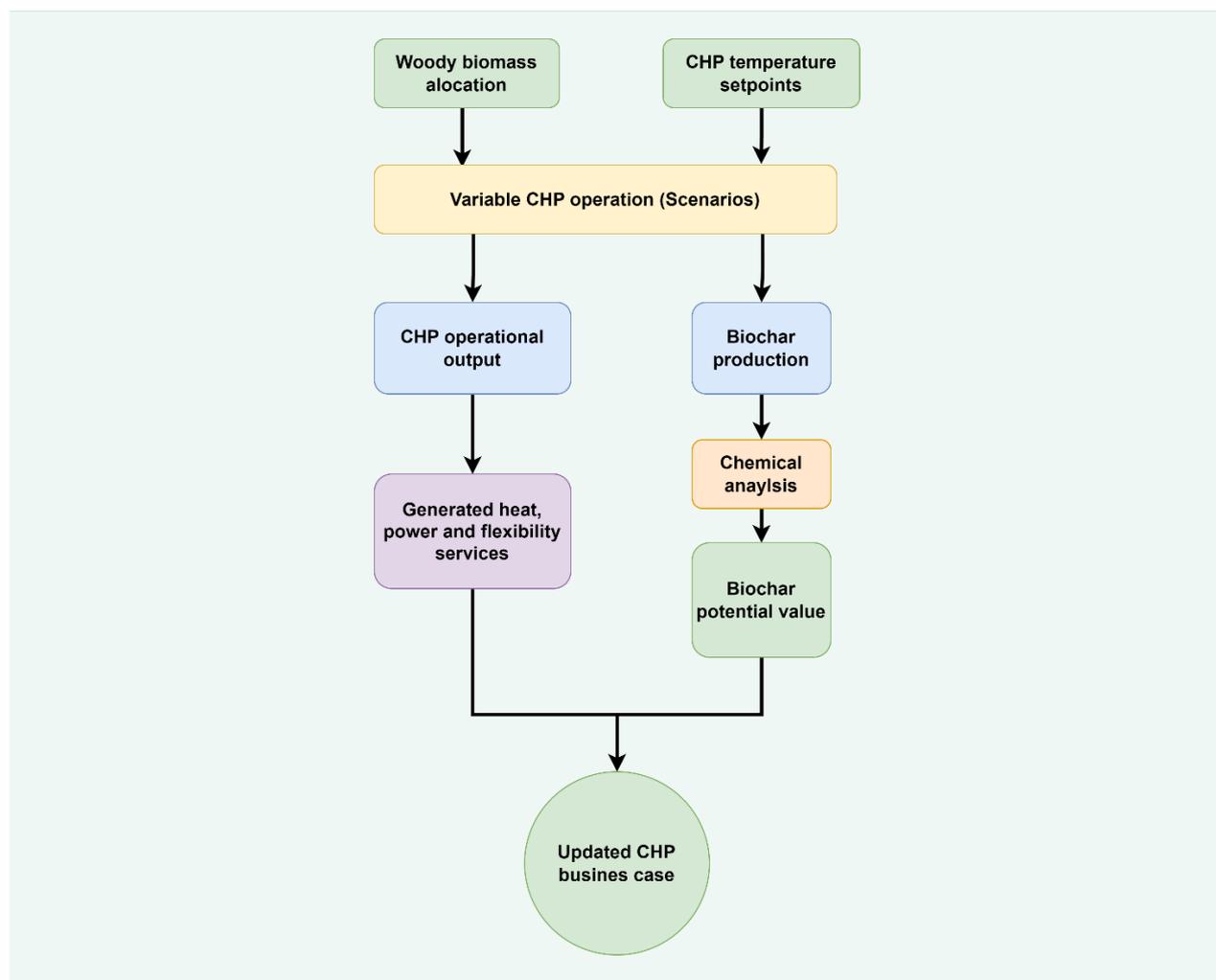| |
|---|
| **Diagram not relevant.** |

Exception paths

Step No.	Event	Description of process / Activity	Info. exchanged	Actor producing the information	Actor receiving the information

No exception paths.

Realization	
Main responsible partners (Author)	• UL
Contributing partners	• KIS
Priority	High

9. Annex II: Use Cases Revision

9.1. ES pilot

UC ES.01 An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	N	The combination of these types of energy sources have been done and applied to crop production.
1. **If not innovative, do you think UC is necessary? (Y/N)**	Y	To create a conducive context for cultivating economically viable subtropical crops and mushrooms, it's imperative to integrate Agri-PV and geothermal energy. This combination not only fulfils the energy requirements of these crops but also enables optimization of energy consumption. Additionally, synergizing the energy generated by the biogas plant with Agri-PV and geothermal sources further enhances overall efficiency and sustainability. In addition to the integration of Agri-PV and geothermal energy, the optimization of the distribution of energy will be also implemented. This optimization involves ensuring that energy generated from various sources, including solar, and biogas, is efficiently distributed and utilized across the agricultural operations.
2. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The possible constraint of geothermal energy will depend on the study of the type of soil and whether it is possible to reach the distance at

		which the probe will be installed. It will also be necessary to cover the light needs of the plants and thus to orient the panels optimally.
3. **Is the UC in line with general market principles? (Y/N)**	Y	Product: The concept addresses the consumer's needs by offering sustainable agricultural products grown using innovative methods that incorporate RES
4. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC ES.02 Biogas/biomethane production from agricultural wastes		
Question	**Answer**	**Explanation/Comments**
2. **Do you think this UC is innovative? (Y/N)**	Y	This UC is innovative since it is going to use an innovative hydrophobic membrane technology to develop vehicle-grade biomethane.
3. **If not innovative, do you think UC is necessary? (Y/N)**	Y	However, it is necessary to develop the process to produce and upgrade biogas to biomethane and the digestate during anaerobic digestion
4. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	Depending on the characteristics of the wastes it will be necessary to optimize the anaerobic digestion phase to maximize both biogas and digestate production.
5. **Is the UC in line with general market principles? (Y/N)**	Y	The market has a great demand for demonstrating the technical performance is a cost-effective, traceable, and sustainable solution for a local- treatment plant
6. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC ES.03 Biofertilizers production from agricultural wastes		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	This UC is innovative since it is going to use the waste from the biogas plant that has not been used for this purpose so far.

2. **If not innovative, do you think UC is necessary? (Y/N)**	Y	However, it is necessary to be able to transform the waste from the biogas plant into biofertilizers useful for crops and herbaceous and forestry crops.
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	Depending on the characteristics of the digestate it will be necessary to use some techniques or others, but it will be possible to transform it into biofertilizer.
4. **Is the UC in line with general market principles? (Y/N)**	Y	The market has a great demand for the reuse of biogas plant wastes.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	Since the bioproduct is specially created – "à la carte" - to enhance the quality of soil
2. **If not innovative, do you think UC is necessary? (Y/N)**	/	/
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	It is possible because its application and development have been tested with experience by the pilot's partners
4. **Is the UC in line with general market principles? (Y/N)**	Y	Since it generates a bioproduct that seeks to maximise the use of the residues that generate biomethane (digestate). Its application in the field will create the reuse of residues, provide economic benefits for crops, and improve soil quality. So, it can be a remarkable product in the agricultural market.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC ES.05 Tests of the behaviour of the product   in agronomic application

Question	Answer	Explanation/Comments
1. Do you think this UC is innovative? (Y/N)	Y	Since the bioproduct is specially created - "à la carte" - to enhance the quality of crops
2. If not innovative, do you think UC is necessary? (Y/N)	/	/
3. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	The testing of agricultural bioproducts must be carried out in the field, in the environmental conditions of the area and in accordance with the needs of the target crops. In this sense, this phase is essential, because if it is not carried out and the tests remain only at the laboratory level, the product's effectiveness when applied in natural conditions may be affected, since the controlled laboratory conditions do not reflect reality.
4. Is the UC in line with general market principles? (Y/N)	Y	This UC ensures the viability and efficiency of the product to launch it on the market. Testing the dose and application time, as well as adjusting it to the crop in the environmental conditions where it is going to be applied, is necessary to reflect the results on which to decide the best way of managing the crops.
5. What are your recommendations regarding this UC? (leave as is/ modify/ remove)	Leave as is	/

9.2. BG pilot

UC BG.01 Smart Agricultural PV Greenhouses and scale-up in combination with thermal energy		
Question	**Answer**	**Explanation/Comments**
1. Do you think this UC is innovative? (Y/N)	Y	Using both photovoltaics and thermal energy from a biogas plant for powering greenhouses is a multifaceted approach to sustainable energy use in agriculture. The task is not only to operate fully independent controlled greenhouses, to rise the yield up to several times per year, but also to reduce electricity consumption from fossil fuels down to zero. Depending on the local regulations, the

		photovoltaics can easily be designed to feed in, to secure weak rural grid, and though provide a second income for farmers, while the given shadowing can support the growing of certain plants inside the greenhouses. By 'pooling' the data of many greenhouses all over Europe, a software can be developed, so that the greenhouse engineers must only enter the fruit-type on it and the software itself drives and controls the greenhouse atmosphere. Implementing self-controlled greenhouses that utilize data from controllers and monitoring systems to optimize conditions is an advanced application of technology in agriculture.
2. **If not innovative, do you think UC is necessary? (Y/N)**	N	
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	Integration of PV and Biogas: Combining PV systems with biogas for thermal energy is technically feasible.
		Smart Greenhouses: The technology for monitoring and controlling greenhouse environments are well-established and widely used in modern agriculture.
		Energy Management: Techniques for managing and optimizing energy usage, including switching between energy sources, like PV to the battery and local utility grid, based on cost or availability, are technically mature.
		Key Constraints:
		Cost & Expertise: Initial investment and technical skills required.
		Maintenance: Systems need ongoing support.
		Regulatory Compliance: ALBENA must follow Energy Act (article 119) to supply energy to subsidiaries.
		Producers may supply their branches, enterprises, and facilities located within the country with electrical energy via direct power lines constructed at their own expense.
		Overproduction: Solutions for surplus energy are needed.
		Infrastructure & Adaptation: Upgrades and customization of local infrastructure will be

		necessary for the implementation of the renewable energies.
4. **Is the UC in line with general market principles? (Y/N)**	Y	The UC involves the creation of Smart Greenhouses that use renewable energy, which is a service addressing the growing consumer need for sustainable and locally produced agricultural products.
		The "product" or the outcome of the Smart Greenhouses, is available within the country where the greenhouses are located. Additionally, the energy produced can be used on-site, reducing the need for transportation and aligning with the concept of localized production. In some countries, the overproduction can be "fed in" the local grid to stabilize it. This approach is highly interesting for local grid provider and rural societies (decentralization)
		The background process involves the optimization and installation of new technologies such as PV panels and thermal systems from biogas plants, as well as the implementation of smart systems for better energy and agricultural management.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	This UC is technically feasible, can be budgeted in a realistic time, and it can be technically realized in a reliable timeline.

UC BG.02 Regional agricultural and other waste analysis and potential biogas production		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	The collaborative research between the business sector ALBENA and academic institutions TRU is an uncommon occurrence in Bulgaria.
		The diversifying of feedstocks as well as the introduction of novel energy crops in Bulgaria could significantly shift the regional biogas production landscape, potentially leading to more sustainable and robust energy solutions.
		Development of Decision-Support Tools: Creating a digital tool for biogas predictions and soil fertilization effects will provide valuable insights and aid for local producers/farmers.

2. **If not innovative, do you think UC is necessary? (Y/N)**		Not applicable.
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The project involves established processes such as biogas production and the use of digital tools for predictive analysis and soil management.
		Potential Constraints:
		Regulatory barriers: Bulgaria's food waste separation regulations are behind European standards.
		Technological limitations: Customization may be needed due to current tech limitations.
		Resource availability: Access to organic waste and biogas plants may be limited, due to missing practices for the separation of food waste.
		Market conditions: Economic feasibility depends on market demand for the end products.
		Infrastructure needs: Adequate infrastructure is essential for both research and implementation.
4. **Is the UC in line with general market principles? (Y/N)**	Y	Product: The service being developed meets the growing need for renewable energy and efficient agricultural waste management, driven by global sustainability efforts.
		Place: The UC outputs, including biogas production techniques and associated knowledge, will be accessible to local farmers and biogas producers.
		Process: Essential steps including research, development, real-world testing in a biogas plant, and digital tool creation are integral to bringing the final product to market.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC BG.03 National and regional regulation and business models implementation to foster rural development		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	The innovation lies in the use people centric approach of establishing local agro-energy

	Y	communities in Bulgaria. In ECOLOOP it will be explored new BMs that will combine "energy cooperatives" and modular design of small biogas and slow pyrolysis units, with focus on circular solutions.
2. If not innovative, do you think UC is necessary? (Y/N)		N/A
3. Is the UC technically feasible? Have you identified any constraints? (Y/N)		It is not applicable, as there are not technical aspects in the UC.
4. Is the UC in line with general market principles? (Y/N)	Y	Local branding label, like: "this product came from sustainable energy produced by local biogas community"
5. What are your recommendations regarding this UC? (leave as is/ modify/ remove)	Leave as is	

9.3. EE pilot

UC EE.01 Wood ash recycling system for forest plantations		
Question	**Answer**	**Explanation/Comments**
1. Do you think this UC is innovative? (Y/N)	N	There exists previous knowledge (mainly from Scandinavia) about the effect of wood ash on the production of deciduous species on organic soils.
2. If not innovative, do you think UC is necessary? (Y/N)	Y	At the moment, there are only a few fragmentary baseline results from small experimental forest plantations in Estonian conditions. The first results from deciduous tree species plantations describing potential production are very promising.
3. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	The bottlenecks are the ash granulation capacity and the overland spreading of ashes by machines on organic soils during all vegetation periods (low peat substrate bearing capacity in early spring or late autumn).
4. Is the UC in line with general market principles? (Y/N)	Y	The availability of wood ash to the customers is good. Wood ash contains essential macro- and micronutrients for plant growth, which enhances tree growth in plantations and

		increases the income from additionally produced biomass. Revenues from the potential production of the plantations exceed the incurred costs.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC EE.02 Carbon calculator for forest plantations		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	The UC is innovative, as previous similar open-access tools have not been created for forest plantations on abandoned agricultural lands.
2. **If not innovative, do you think UC is necessary? (Y/N)**	/	/
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The UC is feasible as it relies on previously developed methods for estimating and modelling plantation growth, yield and carbon content in biomass and soil.
4. **Is the UC in line with general market principles? (Y/N)**	Y	The developed tool will be made available to end users via an open-access online platform. Hence, for end-users, it does not cause expenses but supports in decision-making to increase profit from enhanced biomass production.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC EE.03 New environmental-friendly biostimulants and fertilizers to enhance the production of forest plantations		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	A new environmentally friendly biostimulant, "*arGrow*", has recently entered the market. Its potential to enhance production, alongside mineral fertilizers, will be modelled for forest plantations. Additionally, the impact of fertilization on biodiversity and environmental factors, such as nutrient leaching, will be

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		evaluated. These findings can be integrated into certification systems for forest plantations, helping to legitimize fertilization as a sustainable strategy for increasing renewable production in the region.
2. **If not innovative, do you think UC is necessary? (Y/N)**	/	/
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	New experiments in recently established forest plantations show positive responses on tree early growth
4. **Is the UC in line with general market principles? (Y/N)**	Y	Increasing usage of biostimulant to improve carbon capture in forest plantations. The potential carbon gain will be seen in the open-access carbon calculator.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC EE.04 The potential wood production of different deciduous tree species on different soil types		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	N	There exists previous knowledge about different tree species wood production on different soil types.
2. **If not innovative, do you think UC is necessary? (Y/N)**	Y	The UC provides new information about specific tree species (birches, aspens, alders) wood production on abandoned agricultural lands, while the previous data comes mostly from forestland stands or does not cover the whole rotation cycle in plantations.
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The UC is feasible as it will make use of existing methodologies in forest research for estimating tree growth and yield.
4. **Is the UC in line with general market principles? (Y/N)**	Y	The UC can be seen as a background process for delivering the Carbon calculator.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

9.4. SI pilot

UC SI.01 Optimize the operation and improve the security of the supply of Biomass centre Nazarje		
Question	**Answer**	**Explanation/Comments**
7. Do you think this UC is innovative? (Y/N)	Y	The UC is innovative as it addresses the holistic cross-sector (electricity, heat) integration of the energy assets of Biomass centre Nazarje. The model will be developed to simulate various aspects of cross-function planning and optimally utilize market opportunities while considering security, technical and economic boundaries.
8. If not innovative, do you think UC is necessary? (Y/N)	/	/
9. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	The UC is feasible as the integration of the assets with the aggregator platform has already been established in other projects. The aggregator has a proven track record of developing complex real-time technical and market optimization models of different energy assets and simulating and emulating various aspects to evaluate different energy strategies (e.g., TOTEX minimization).
10. Is the UC in line with general market principles? (Y/N)	Y	-　　　Product: The UC will enable additional monetization of the existing energy assets and thus address consumer needs. - -　　　Place: The integration of the energy assets with the aggregator platform will be done via edge devices. These devices will be connected to the cloud and thus available to the consumer. The real-time technical and market optimization module will run locally on the aggregator's platform. - -　　　Process: The concept of the process has been developed and confirmed by both involved parties.
11. What are your recommendations regarding this UC? (leave as is/ modify/ remove)	Leave as is	/

UC SI.02 Utilization of flexibility of the Biomass centre Nazarje

Question	Answer	Explanation/Comments
1. Do you think this UC is innovative? (Y/N)	N	Ancillary services offering is an established product.
2. If not innovative, do you think UC is necessary? (Y/N)	Y	The UC includes the development of the baseline and flexibility model based on historical measurements while utilizing advanced machine learning algorithms. Furthermore, the UC includes availability, security, technical and economic boundaries and thus fully integrates a user-centric approach.
3. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	The UC is feasible as the integration of the assets with the aggregator platform has already been established in other projects. Development and implementation of the baseline and flexibility model are feasible as the aggregator possesses extended knowledge and experience in this field.
4. Is the UC in line with general market principles? (Y/N)	Y	Product: The UC will enable additional monetization of the existing energy assets and thus address consumer needs. Place: The integration of the energy assets with the aggregator platform will be done via edge devices. These devices will be connected to the cloud and thus available to the consumer. Process: The concept of the process has been developed and confirmed by both involved parties.
5. What are your recommendations regarding this UC? (leave as is/ modify/ remove)	Leave as is	/

UC SI.03 Design of a modular biomass slow pyrolysis system solution		
Question	**Answer**	**Explanation/Comments**
1. Do you think this UC is innovative? (Y/N)	Y	This UC will enable the production, design and sales of small modular CHP units, tailored to smaller sawmills and farmer needs
2. If not innovative, do you think UC is necessary? (Y/N)	/	/

3. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	The UC is feasible as the overall CHP systems are designed in cascade and thus smaller unit design is possible.
4. Is the UC in line with general market principles? (Y/N)	Y	Yes, small-scale CHPs are important in phasing out of gas and fossil fuel-based heating solutions. It aligns with several market principles. As the modular design is based on smallest building block, the price of the final product is lower as compared to classical big cascade systems, making it more accessible to smaller investors. As it deviates from classical big CHP systems, a new market segment of farmers, small sawmill owners and other potential investors are now a new target audience for this small-scale CHP unit.
5. What are your recommendations regarding this UC? (leave as is/ modify/ remove)	Leave as is	/

UC SI.04 Biochar maximum utilization		
Question	**Answer**	**Explanation/Comments**
1. Do you think this UC is innovative? (Y/N)	Y	It expands the business model of CHP operation from heat and energy generation to additional production of biochar as a result of CHP operation
2. If not innovative, do you think UC is necessary? (Y/N)	/	/
3. Is the UC technically feasible? Have you identified any constraints? (Y/N)	Y	As the CHP enables variable temperature setpoint, it allows controlling the ash/biochar output of the CHP operation.
4. Is the UC in line with general market principles? (Y/N)	Y	New, bio-grade materials for carbon capture present a new environmentally friendly and sustainable fertilizer solution. This UC will expand the business portfolio of existing CHP and additional modular ones. It is aligned with market principles as it introduces new side product, which can be produced thus providing additional revenue stream. It additionally goes in parallel with the utilization of the flexibility features of the CHPS operation. As the CHP enables flexible/variable temperature setpoint for the burners, the low temperature operation

		results in non-optimal burning process of the biomass, resulting in the char as a side project. The biochar presents the environmentally friendly alternative to chemical-grade fertilizers and serves as a carbon capture measure.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	/

UC SI.05 Biomethane from biogas power plant utilization for agricultural machinery		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	The UC introduces a new approach by leveraging biogas and biomethane production capabilities to power agricultural machinery, offering a sustainable alternative to traditional fuels and contributing to energy self-sufficiency in agriculture.
2. **If not innovative, do you think UC is necessary? (Y/N)**	/	/
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The UC is reasonable, leveraging KIS's expertise in biogas technology. Constraints might include scalability and the integration of biomethane into existing machinery, requiring modifications or adaptations.
4. **Is the UC in line with general market principles? (Y/N)**	Y	This UC aligns with market principles by providing a sustainable "product" (biomethane) for agricultural machinery, accessible through KIS's infrastructure and supported by a well-defined process for biogas production and conversion to biomethane.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Leave as is	Given its alignment with sustainability goals and KIS's capabilities, the UC should be maintained. Any potential modifications should focus on enhancing the efficiency and scalability of biomethane production and utilization in machinery.

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UC SI.06 Redesign of subsidies and new business models for biogas		
Question	**Answer**	**Explanation/Comments**
1. **Do you think this UC is innovative? (Y/N)**	Y	The UC is innovative by proposing new BMs and subsidy structures for biogas, addressing financial and operational barriers in renewable energy adoption, specifically tailored to KIS's context and capabilities in biogas production.
2. **If not innovative, do you think UC is necessary? (Y/N)**	/	/
3. **Is the UC technically feasible? Have you identified any constraints? (Y/N)**	Y	The UC is technically feasible, with KIS's ongoing work in biogas as a foundation. Constraints may include regulatory challenges and market acceptance of new BMs and subsidies.
4. **Is the UC in line with general market principles? (Y/N)**	Y	The UC aligns with market principles by exploring new BMs and subsidies that meet the needs of the biogas market, are accessible to stakeholders and are supported by a comprehensive process for implementation and adoption.
5. **What are your recommendations regarding this UC? (leave as is/ modify/ remove)**	Modify	Modifications may be necessary to address potential regulatory and market challenges. This includes detailed market analysis and stakeholder engagement to test and refine the proposed models and subsidies.

10.   Annex III: Requirements

Requirement ID	K1_001
Description	[UC SI.05] When the biogas plant is upgraded to produce biomethane, the produced biomethane shall comply with EU standards for automotive fuels (EN 16723-2:2018), ensuring its suitability for use in automotive engines.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Operational requirements

Rationale	To ensure that biomethane produced at the biogas plant is of a quality that meets or exceeds the requirements set forth by EU standards for automotive fuels, facilitating its broader acceptance and use.
Acceptance criteria	Biomethane production is consistently in compliance with EN 16723-2:2018 standards. Verification of biomethane quality must be conducted through regular testing or measurements.
Priority	5
Comments	
Author	Zan Mongus (KIS)

Requirement ID	K1_002
Description	[UC ES.02] GENIA and INDEREN must request an Environmental Activity License at the location of the biogas pilot site.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Legal requirements
Rationale	Obtaining the environmental license is mandatory to continue with the construction procedures of the biogas production pilot.
Acceptance criteria	The system must comply with the environmental legislation set in the country where it is installed.
Priority	5
Comments	
Author	Ana Fernández (GENIA)

Requirement ID	K1_003
Description	[UC ES.02] [UC SI.05] The biogas plant shall operate according to safety procedures.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Operational requirements

Rationale	Ensuring the safety of personnel, equipment, and the surrounding environment during every stage of the biogas plant operations.
Acceptance criteria	The biogas plant design and operations adhere to all safety regulations and standards.
Priority	5
Comments	ATEX Directive (2014/34/EU). Emergency Response Planning. Environmental Regulations.
Author	Kevin Rodriguez (INDEREN)

Requirement ID	**K1_004**
Description	[UC ES.02] [UC ES.03] The anaerobic digestion process shall be optimized for maximum production of biogas and digestate for the production of biofertilizer.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Performance requirements
Rationale	This optimization is essential to ensure efficient resource utilization, promoting sustainability by maximizing the outputs of both energy and nutrient-rich digestate.
Acceptance criteria	The anaerobic digestion system shall achieve a daily biogas production output within the specified target range.
Priority	5
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	**K1_005**
Description	[UC ES.02] The biogas plant should be designed and implemented to be easily maintainable, ensure long-term operation efficiently and to reduce downtime.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Maintainability and support requirements

Rationale	Maintainability and support are crucial for the sustained performance of the biogas plant system.
Acceptance criteria	The system design shall include clear documentation outlining maintenance procedures, schedules, and troubleshooting guidelines.
Priority	4
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K1_008
Description	[UC SI.05] Implement an enhanced monitoring system for the biogas production process to optimize energy output.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Functional and data requirements
Rationale	To ensure the biogas plant operates at peak efficiency and maximizes energy production, KIS implements an enhanced monitoring system in the biogas production unit.
Acceptance criteria	The system must provide real-time data that shows an increase in biogas production efficiency.
Priority	4
Comments	
Author	Zan Mongus (KIS)

Requirement ID	K1_009
Description	[UC SI.05] A monitoring system will be implemented in the second unit to calculate the production rate to biomethane.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	The scope of the product

Rationale	To enable accurate tracking and comparison of biogas output and biomethane conversion efficiency across different pilot sites within the ECOLOOP project.
Acceptance criteria	The facility must measure biogas production in cubic meters (m³) and biomethane conversion rates as a percentage, with a precision of ±1%. These metrics must be recorded consistently to provide a reliable basis for comparison with other pilot sites.
Priority	5
Comments	Upon upgrading the 1st stage of biogas production with the biomethane production unit, a second monitoring system will be implemented in the biomethane production unit to calculate the conversion rate from biogas to biomethane.
Author	Zan Mongus (KIS)

Requirement ID	**K1_010**
Description	[UC SI.05] Enhance the biogas cleaning process to improve biomethane purity.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	The scope of the product
Rationale	To meet the high-quality standards required for biomethane use in energy applications.
Acceptance criteria	Achieve 95-99% methane purity in the biomethane output.
Priority	5
Comments	KIS and specialist that will assist with the second unit that converts biogas into biomethane will implement new and efficient technologies that will ensure and increase the biomethane purity.
Author	Zan Mongus (KIS)

Requirement ID	**K1_011**
Description	[UC BG.02] The Biogas production system must be capable of processing diverse organic waste types from agriculture and local sources.
Classification	KER 1: Innovative and efficient biogas production and conversion process

Type	Functional and data requirements
Rationale	Utilizing a wide range of local organic waste types for Biogas production can significantly contribute to the circular economy, reduce waste, and provide a RES. Understanding the Biogas potential of various waste types and their impact is the base and so absolutely necessary.
Acceptance criteria	The system shall demonstrate the ability to: Process various identified organic waste types with a conversion efficiency rate benchmarked against industry standards.
Priority	5
Comments	This requirement is designed to ensure that the biogas production process in UC BG.02 is not only efficient and sustainable but also contributes positively to the local agricultural ecosystem and supports ALBENA's goals within the ECOLOOP project framework. Assessing their biogas production potential through comprehensive research and real-world testing.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	KI_012
Description	[UC ES.02] The digester diet should be adapted to the waste generated at each stage of the growing cycle.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Functional and data requirements
Rationale	To meet the circularity objective, the inputs included in the digester's diet must be adapted to the availability of agricultural waste at each time of the year, as fruit and vegetable production responds to its seasonality.
Acceptance criteria	Inputs must be locally sourced and ensure the continuity of the biogas/biomethane production process.
Priority	5
Comments	
Author	Bárbara Carreras (AVA-ASAJA)

Requirement ID	K1_013
Description	[UC ES.02] The digester diet should be adapted to the waste based on the crops grown in the area.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Functional and data requirements
Rationale	To meet the circularity objective, the digester's inputs must correspond to the reality of the area. In other words, the waste must come from crops that are adapted to the implementation area and are widely cultivated.
Acceptance criteria	Inputs (agricultural waste) must be originated in the area.
Priority	5
Comments	
Author	Bárbara Carreras (AVA-ASAJA)

Requirement ID	K1_014
Description	[UC SI.05] Develop and compile a comprehensive guidebook that serves for outlining the processes for initiating a biogas and biomethane plant project.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	User documentation and training
Rationale	It aims to simplify project initiation and enhance operational efficiency, promoting renewable energy use among farmers and foresters.
Acceptance criteria	Guidebook that outlines starting biogas/biomethane projects and their operational protocols, aiming to simplify project initiation and system management for stakeholders, thereby enhancing renewable energy adoption in agriculture.
Priority	5
Comments	The guidebook, developed with expertise from KIS, UL, and partners, offers a concise resource on acquiring permits, compliance, and best practices for biogas to biomethane conversion, focusing on agricultural machinery applications.
Author	Zan Mongus (KIS)

Requirement ID	KI_015
Description	[UC ES.02] Define the agriculture waste diet to include in the digestate.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	The scope of the work
Rationale	Characterization of agricultural residues, designs the anaerobic digester, plans waste pre-treatment, and outlines biogas unit treatment.
Acceptance criteria	The system must comply with the biogas production KPI set in the Gran Agreement.
Priority	5
Comments	
Author	Ana Fernández (GENIA)

Requirement ID	KI_016
Description	[UC ES.02] The system shall incorporate a monitoring equipment of control parameters (pH, oxygen, etc.)
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Functional and data requirements
Rationale	Process control system detects equipment malfunction or system failure.
Acceptance criteria	The system must comply with the operational requirements related to specified daily capacity and quality standards.
Priority	4
Comments	
Author	Ana Fernández (GENIA)

Requirement ID	KI_018
Description	[UC ES.02] Define the responsibility of the operation and maintenance expenses of biogas Spanish pilot.

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Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Operational requirements
Rationale	Construction and operation of the biogas plant, the anaerobic digester is built and put into operation.
Acceptance criteria	Quantity of budget and which partner should allocate it to operate and maintain the biogas plant in the Spanish pilot.
Priority	4
Comments	
Author	Ana Fernández (GENIA)

Requirement ID	K1_019
Description	[UC SI.05] Establish a training program for additional KIS staff on the operational management of the biogas to biomethane conversion process and machine refuelling.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	User documentation and training
Rationale	To ensure that all personnel are proficient in the latest conversion technologies and processes.
Acceptance criteria	All operational staff are trained, and an increase in biomethane production efficiency is observed.
Priority	4
Comments	The training program will be conducted with experts on agro-machinery transformation to biomethane fuel.
Author	Zan Mongus (KIS)

Requirement ID	K1_020
Description	[UC SI.05] Agricultural machinery at KIS, when present, shall be adapted or retrofitted to run on biomethane, enabling efficient and sustainable agricultural tasks using biomethane as a fuel.

Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	The purpose of the product
Rationale	To promote the use of biomethane as a clean and sustainable fuel alternative in agriculture, reducing reliance on traditional fossil fuels and enhancing energy independence for farmers and agricultural workers.
Acceptance criteria	Agricultural machinery must be successfully adapted to run on biomethane with no loss in performance compared to conventional fuels. The machinery should be able to perform all standard agricultural tasks effectively using biomethane.
Priority	4
Comments	
Author	Zan Mongus (KIS)

Requirement ID	K1_021
Description	[UC BG.01] Optimized energy output and yield makes highly qualified agricultural and biological engineers necessary.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Operational requirements
Rationale	The optimized functioning of a Biogas Plant or any other thermal Power plant makes it necessary, that the agricultural and the chemical/biological engineers participate in continuous trainings.
Acceptance criteria	High degree of engineering and biological/chemical knowledge.
Priority	5
Comments	In rural areas it is not easy to find open minded engineers, who have a wide field of biological and chemical knowledge.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	KI_022
Description	[UC ES.02] [UC SI.05] All operations within the biogas to biomethane conversion process must adhere to national and EU environmental and safety regulations.
Classification	KER 1: Innovative and efficient biogas production and conversion process
Type	Legal requirements
Rationale	Compliance ensures the plant operates within legal environmental and safety standards, preventing legal liabilities and promoting sustainable practices.
Acceptance criteria	Obtain and maintain all necessary environmental and operational permits from relevant authorities.
Priority	5
Comments	
Author	Zan Mongus (KIS)

Requirement ID	KII_004
Description	[UC SI.01] [UC SI.02] The aggregator platform shall collect data from flexibility assets.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Functional and data requirements
Rationale	The aggregator has to collect the measurement data of the assets to successfully perform the ancillary services and technical and economic optimization calculation.
Acceptance criteria	Data is collected in time interval <= 15 minutes.
Priority	5
Comments	
Author	Klemen Kosovinc (SETUP)

Requirement ID	K11_005
Description	[UC SI.01] [UC SI.02] The optimal technical and economic optimization calculation shall be executed in less than 15 minutes.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Functional and data requirements
Rationale	The aggregator should be able to perform the optimal technical and economic calculation in less than 15 minutes to send new baselines and exploit market opportunities.
Acceptance criteria	The optimisation module should take <= 15 minutes.
Priority	5
Comments	
Author	Klemen Kosovinc (SETUP)

Requirement ID	K11_006
Description	[UC SI.02] The aggregator shall activate the flexibility asset, when the aggregator receives the signal from the system operator.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Functional and data requirements
Rationale	For successful participation in the mFRR market, the asset should be able to perform activation after receiving signal from the aggregator.
Acceptance criteria	When the activation signal is sent, the asset can deliver the agreed power in <=12,5 min.
Priority	5
Comments	
Author	Klemen Kosovinc (SETUP)

Requirement ID	K11_007
Description	[UC SI.01] When the operational set point is received from the aggregator, the maximal set-point error shall be 5%.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Functional and data requirements
Rationale	For the successful realization of the new operational scenario, the assets should receive and set new set-points.
Acceptance criteria	The new power of the asset is the defined set point ± 5%. *Other value could be defined for individual assets if <=5% cannot be achieved.
Priority	5
Comments	
Author	Klemen Kosovinc (SETUP)

Requirement ID	K11_009
Description	[UC SI.02] The CHP is operating stable and efficient at variable temperature setpoints.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Performance requirements
Rationale	The CHP unit must remain responsive and in stable operation under variable temperature setpoint.
Acceptance criteria	The controlled assets remain stable and deliver expected electric and thermal power outputs.
Priority	5
Comments	
Author	David Speh (BIOMASA)

Requirement ID	K11_010
Description	[UC SI.03] CHP system components must have modular functionality in order to design several unit types in terms of power output and storage size.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	The scope of the product
Rationale	The modular design of the Slow pyrolysis system unit must offer several variants of the product, where smaller building blocks are connected in order to different modular unit types provide several.
Acceptance criteria	Minimum 2 units can be connected in series or parallel in order to demonstrate modularity of the system.
Priority	3
Comments	
Author	David Speh (BIOMASA)

Requirement ID	K11_011
Description	[UC SI.04] The designated CHP unit must allow Variable temperature setpoint operation.
Classification	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Type	Operational requirements
Rationale	The CHP unit must allow controlled and repeatable temperature setpoint setting in order to investigate the biochar production process in the CHP operation.
Acceptance criteria	Temperature range from min. To maximal temperature setpoint must allow increments of 5% in order to retrieve accurate temperature/power and biochar production curves.
Priority	5
Comments	
Author	David Speh (BIOMASA)

Requirement ID	K2_001
Description	[UC ES.01] The system shall effectively optimize the distribution of solar energy to cover the energy needs of geothermal energy.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	Ensuring an efficient utilization of solar energy is mandatory to meet the energy demands of geothermal energy.
Acceptance criteria	The system successfully allocates solar energy to support geothermal energy without compromising overall efficiency.
Priority	5
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K2_002
Description	[UC ES.01] The system shall incorporate a real-time monitoring and adaptation mechanisms to achieve an optimal distribution of different renewable energies when energy demand and environmental conditions change.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	Real-time monitoring and control enable the system to respond swiftly to changing conditions, maintaining the optimal balance for energy distribution.
Acceptance criteria	The system demonstrates the ability to autonomously adjust the distribution of energy sources in real-time, optimizing energy distribution efficiency.
Priority	5
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K2_003
Description	[UC ES.01] The system shall efficiently integrate Solar PV and Geothermal Energy to maintain optimal conditions for agricultural crops across different seasons.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	The purpose of the product
Rationale	The combination of Solar PV and Geothermal Energy must be used to ensure ideal conditions for crops throughout the year.
Acceptance criteria	The system successfully integrates Solar PV and Geothermal Energy, achieving a minimum of 80% efficiency in maintaining ideal conditions for crops.
Priority	5
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K2_004
Description	[UC ES.01] The system shall integrate various sensors tailored to address the specific needs of crops, including but not limited to moisture, temperature, and CO_2 sensors.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	To optimize agricultural productivity, monitoring and address the specific requirements of crops in real-time is essential, enabling data-driven decision-making for energy efficiency and promoting optimal crop health.
Acceptance criteria	The sensor network provides real-time, accurate data on essential environmental factors, facilitating a data-driven approach to greenhouse management that enhances crop yields and resource use efficiency.
Priority	4

Comments	It is essential to continuously collect inside and outside data, to be able to foresee changes and to be able to react faster on outside changes.
	Moisture (%), temperature (°C), CO_2 (Ppm)
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K2_007
Description	[UC SI.01] The interoperability and interconnectivity of various RES technologies must be ensured.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Operational requirements
Rationale	The installed RES technologies (PV, BESS and CHP) must communicate and be accessible with central control/monitor platform.
Acceptance criteria	All installed assets are remotely monitored and controlled if required by the process.
Priority	5
Comments	
Author	David Speh (BIOMASA)

Requirement ID	K2_008
Description	[UC BG.01] Publishing a catalogue of legal requirements for each Country to apply and to install RES.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Legal requirements
Rationale	Lack of knowledge stops Farmers to invest and to apply for connection agreements and building permits for RES.
Acceptance criteria	A description for all/each European Countries is needed, that describe farmers how to apply for installation and connection of RES.

Priority	5
Comments	Many farmers are sceptical of RES, and do not know, how to apply for connection agreements, building permits etc. This can be different in every country.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	**K2_009**
Description	[UC BG.01] The new photovoltaics must be positioned to provide most possible output.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	To ensure that the Agri-PV system operates at optimal efficiency throughout the day to changing sunlight conditions.
Acceptance criteria	The system demonstrates that the modified orientation is a more most suitable option, resulting in a gain in annual energy production compared to no reorientation.
Priority	4
Comments	This requirement supports the goal of maximizing renewable energy production (CO_2 energy free) while supporting agricultural activities. This secures the smart Agri-PV system to work efficiently.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	**K2_010**
Description	[UC BG.01] The smart Agri-PV system shall be dimensioned so that the solar energy is able to cover the energy needs of the greenhouses.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements

Rationale	Ensuring an efficient utilization of PV energy is mandatory to meet the energy demands of the greenhouses.
Acceptance criteria	The system successfully allocates PV energy and thermal energy to support greenhouses energy needs without compromising overall efficiency.
Priority	5
Comments	Long-term greenhouses shall be not depending on local utility.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	**K2_011**
Description	[UC BG.01] The smart Agri-PV system, in combination with the thermal energy system of the biogas plant shall automatically adjust to meet the energy demands of the greenhouses.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	The integration of smart Agri-PV with thermal energy from the biogas systems is critical for maintaining ideal growth conditions in the greenhouses while maximizing the use of RES and minimizing CO_2 emissions.
Acceptance criteria	The integrated system must demonstrate the ability to maintain target temperature and illumination levels within the greenhouses, utilizing up 50% RES, leading to a measurable reduction in CO_2 emissions and energy costs.
Priority	5
Comments	This requirement emphasizes the need for an integrated approach to control sustainable agricultural practices in the greenhouses. This ensures optimal growth conditions.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	**K2_012**
Description	[UC BG.01] The different RES must include real-time monitoring and an automatism to optimize the distribution of renewable energies, depending on requirements of the greenhouses.

Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	Functional and data requirements
Rationale	Continuous monitoring and adaptive control are essential for maintaining an optimal balance between energy supply from the Agri-PV and thermal energy sources and the energy demand of the greenhouses, ensuring sustainable and most efficient operations.
Acceptance criteria	The integrated system demonstrates the capability to autonomously adjust energy distribution in real-time, maintaining at least 10% efficiency in energy utilization for greenhouse operations.
Priority	5
Comments	All pilots must agree upon a frequency of data transfer, to provide and to achieve comparable data.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	K2_013
Description	[UC BG.01] ALBENA's smart Agri-PV system, in conjunction with thermal energy from the biogas plant, shall provide a fertile atmosphere in the greenhouses.
Classification	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Type	The purpose of the product
Rationale	Leveraging both PV and (biogas) thermal energy sources is key to providing stable and optimal growth conditions for crops year-round, enhancing yield and sustainability, not matter the environmental situation.
Acceptance criteria	The system achieves seamless integration of PV and (biogas) thermal energy, maintaining ideal crop growth conditions with an efficiency of 15% across different seasons in the first 2 years.
Priority	5
Comments	The percentage in yield raise is always depending on the crop, planted. The greenhouse atmosphere must be predetermined, depending on the planted crop.

Author	Kai Vogelhaupt (ALBENA)

Requirement ID	K3_001
Description	[UC ES.03] Farmers, cooperatives and irrigation communities must be interested in the application of the bioproducts generated.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	The client, the customer and other stakeholders
Rationale	The bio-products produced must be of interest to farmers. To do so, they must meet the nutritional requirements of plants, just as commercial fertilisers do, while not harming the plant and the soil.
Acceptance criteria	Number of stakeholders interested in test and applicate the bioproducts generated within the project.
Priority	4
Comments	
Author	Bárbara Carreras (AVA-ASAJA)

Requirement ID	K3_002
Description	[UC ES.02] [UC ES.03] Definition of permitted substrates for obtaining digestate that can be used to produce a biofertilizer that can be commercialized.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Legal requirements
Rationale	To be able to commercialize the biofertilizer developed from the digestate as a fertilizer.
Acceptance criteria	Comply with Annex II of regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 and related regulations.
Priority	5

Comments	
Author	José Antonio Rodríguez (FERTINAGRO)

Requirement ID	**K3_003**
Description	[UC BG.01] Soil investigation has to be made on every field, to have transparency about the nutritious status of the soil, and which ingredients need to be added, depending on the crop.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Relevant facts and assumptions
Rationale	Determining the right crops and vegetables to grow involves assessing the soil's properties and nutrient levels. The measured and tested key factors are: 1) Nutrient Levels: • Macronutrients: Evaluate levels of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). These nutrients significantly impact plant growth and yield. • Micronutrients: Check for trace elements such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu). These are crucial for healthy plant development. 2) Soil pH: • Soil acidity or alkalinity affects nutrient availability. Most plants thrive in slightly acidic to neutral pH (around 6.0 l to 6.5 l). 3) Organic Matter Content: • Organic matter influences soil structure, water retention, and nutrient availability. Higher organic matter content generally supports better crop growth. 4) Texture and Structure: • Soil texture (clay, loam, sand) affects water retention and aeration. • Soil structure (crumbly, cloddy) impacts root penetration and water movement. 5) Soil Life and Health: • Observe signs of soil life (worms, organisms) and their activity. Healthy soil ecosystems support plant growth. 6) Irrigation Management: • Understand soil moisture patterns and irrigation needs.
Acceptance criteria	Laboratory results in regard to the N, P and K values of the defined fields.
Priority	5

Comments	Optimization of the yield needs clear facts about the soil status.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	K3_004
Description	[UC ES.04] [UC ES.05] The application of the product must cover the variety of crops in the area.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Users of the product
Rationale	The economic and environmental benefits of the application of the product extend to a greater proportion of farmers.
Acceptance criteria	The set of selected crops occupies more than 40% of the useful agricultural surface of the pilot study area.
Priority	4
Comments	
Author	UPV

Requirement ID	K3_005
Description	[Global] If there are many farmers interested in having plots for experimentation, then selection criteria must be established.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	From the functional and analytical point of view in the laboratory, it is not possible to experiment on the entire surface of the study pilot.
Acceptance criteria	The criteria of proximity, priority crops and extension of the crop surface will be key to jointly select a maximum of 5-6 study plots.
Priority	5

Comments	
Author	UPV

Requirement ID	K3_012
Description	[UC EE.03] Novel biostimulant should increase the potential production of forest plantations.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	To be able to commercialize biostimulants as the biofertilizer. The potential production increase from the using of biostimulant as fertilizer will be modelled for forest plantations.
Acceptance criteria	The using of biostimulants and fertilizers adhere to all safety regulations and standards.
Priority	5
Comments	
Author	Katri Ots (EULS)

Requirement ID	K3_013
Description	[UC EE.01] Recycling of wood ash from energy waste as biofertilizer should increase the potential production of forest plantations.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	To be able to commercialize wood ash as the biofertilizer. The potential production increase from the using of wood ash as fertilizer will be modelled for forest plantations.
Acceptance criteria	The using of wood ash adheres to all safety regulations and standards.
Priority	5

Comments	
Author	Katri Ots (EULS)

Requirement ID	K3_015
Description	[UC EE.01] The yield productivity data of plantations treated by wood ash must be collected.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Based on the potential production of plantations on cut-away peatlands (organic soils) treated with wood ash, growth tables can be compiled.
Acceptance criteria	Growth and yield models of plantations in organic soils for carbon footprint model have been created.
Priority	4
Comments	The yield and productivity data from wood ash treated experimental plots will be compared to control area (untreated plots). The respective methodology has been developed.
Author	Katri Ots (EULS)

Requirement ID	K3_016
Description	[UC EE.01] The effect of wood ash on biodiversity and environment of cut-away peatlands must be monitored.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Description of changes in biodiversity under wood ash fertilization.
Acceptance criteria	Changes in biodiversity and in environment after treating with wood ash have been described.
Priority	5

Comments	The effect will be estimated in comparative study where sites treated with conventional fertilization, wood ash and untreated sites are analysed.
Author	Katri Ots (EULS)

Requirement ID	K3_017
Description	[UC EE.03] Environmental impact of biostimulant in comparison with conventional fertilization should be evaluated.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Description of nutrients leaching under biostimulant on groundwater quality.
Acceptance criteria	The using of biostimulant reduces nutrients leaching to groundwater in comparison with mineral fertilizers.
Priority	4
Comments	
Author	Katri Ots (EULS)

Requirement ID	K3_018
Description	[UC EE.03] Impact of biostimulant on soil organic carbon pools should be measured.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Responses of biostimulant on soil organic carbon sequestration in forest plantations will be estimated.
Acceptance criteria	Using of biostimulant does not reduce soil organic carbon reserves.
Priority	4
Comments	

Author	Katri Ots (EULS)

Requirement ID	K3_019
Description	[UC EE.04] Basic tree growth data must be collected from sample plots of different tree species plantations.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Based on tree growth data from sample plots, growth tables of forest plantations covering the whole rotation cycle can be compiled.
Acceptance criteria	Tree growth data tables, as required for yield and biomass modelling, have been compiled.
Priority	4
Comments	Tree growth data tables, as required for yield and biomass modelling, have been compiled.
Author	Katri Ots (EULS)

Requirement ID	K3_020
Description	[UC EE.04] The yield of plantations must be distributed into wood assortments.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Functional and data requirements
Rationale	Based on yield tables, volume of different assortments (energy wood, pulpwood, logs) is estimated.
Acceptance criteria	Wood assortment tables have been compiled.
Priority	4
Comments	
Author	Katri Ots (EULS)

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Requirement ID	K3_021
Description	[UC ES.04] [UC ES.05] A preliminary analysis of soil should be carried out.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	The scope of the product
Rationale	If soil is not degraded and is in good health, applying the bioproduct or requiring higher doses may not be necessary. Effectiveness may depend on the needs and condition of the soil.
Acceptance criteria	A recent soil analysis (at least one in less than a year) to know its status is necessary.
Priority	4
Comments	
Author	UPV_ECOLOOP

Requirement ID	K3_022
Description	[UC ES.04] [UC ES.05] Soil managers should know about soil indicators that they are testing.
Classification	KER 3: Bioproducts to create positive effects on soil health, biodiversity and groundwater
Type	Users of the product
Rationale	If soil managers do not know the soil indicator, they will not be able to interconnect the application of products and improvements on the soil and its crops.
Acceptance criteria	Soil managers should read the indicators factsheets that UPV will prepare.
Priority	5
Comments	
Author	UPV_ECOLOOP

Requirement ID	K4_001
Description	[Global] The tool must prevent the access and use by unauthorized users by means of authentication mechanisms.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Security requirements
Rationale	The tool will manage sensible information that should not be accessed by unauthorised users.
Acceptance criteria	The user is requested to provide valid credentials in order to access the tool.
Priority	5
Comments	
Author	Diego Garcia (ETRA)

Requirement ID	K4_002
Description	[Global] The tool must support multitenancy.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	Maintenance of multitenant tools is easier and cleaner than several on-premises deployments.
Acceptance criteria	A single instance of the tool supports all pilots.
Priority	5
Comments	
Author	Diego Garcia (ETRA)

Requirement ID	K4_003
Description	[Global] An identified user must only be able to access the information they are granted permission to.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	The tool will manage sensible information that should only be accessed by authorised users.
Acceptance criteria	After providing valid credentials, the user is only able to access the information they are entitled to.
Priority	5
Comments	
Author	Diego Garcia (ETRA)

Requirement ID	K4_004
Description	[Global] Measuring equipment in the pilots must have (or be complemented with) IoT capabilities in order to send (near) real-time data to the tool.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Operational requirements
Rationale	Measuring data is essential both for basic monitoring of the pilot and to feed the algorithms of the tool.
Acceptance criteria	Measurements from field equipment are periodically received by the tool.
Priority	5
Comments	IoT capabilities include: MQTT, AMQP, HTTP API, KAFKA, etc. The frequency of the data will be determined by the needs of the pilots and the technical limitations of the field equipment.
Author	Diego Garcia (ETRA)

Requirement ID	K4_005
Description	[Global] The tool will provide a dynamic model of the pilots that includes their key elements and their current status.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	Schematic representation of real-life elements makes it easier to identify their status and potential issues.
Acceptance criteria	The authorized user can visualize the model of their associated pilot.
Priority	5
Comments	Key elements will depend on the pilot goals and technical restrictions. They will typically include energy systems (Agri-PV, biogas, thermal storage, etc.), agricultural and forestry assets (crops, forests, etc.), and the processes in evaluation (new bioproducts, RES-based protocols, etc.).
Author	Diego Garcia (ETRA)

Requirement ID	K4_008
Description	[UC ES.01] The tool will coordinate the optimal combination of PV, geothermal, and biogas systems in the greenhouse plant.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	Different technologies in use must be managed in combined form rather than separately.
Acceptance criteria	The plant operator will supervise the operation of the tool and provide feedback if needed.
Priority	5
Comments	
Author	Diego Garcia (ETRA)

Requirement ID	K4_009
Description	[UC ES.03] The tool will integrate with the SCADA to operate over the biogas plant and its production (biogas, organic digestates).
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	The everyday operation of the plant is managed by the SCADA. In order to actuate over it, an integration with the system is needed.
Acceptance criteria	The biogas plant can receive commands generated by the tool and performs the expected actions.
Priority	5
Comments	Not all SCADA systems allow external influence on its operation. It is necessary to study if the system that will be set up in the pilot has these capabilities (e.g. communication protocols such as OPC UA, DNP3, or Modbus), and try to find a workaround otherwise.
Author	Diego Garcia (ETRA)

Requirement ID	K4_010
Description	[UC BG.01] The decision support tool will integrate and manage the operation of the Agri PV greenhouses and their systems to ensure optimal energy use and crop growth conditions.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	Efficient and fast management of integrated RES is crucial for maintaining ideal growth environments within greenhouses while maximizing energy efficiency and sustainability. Moreover, the operator needs reporting on the current, historical, and foreseen status of the plants to assess their validity.
Acceptance criteria	The tool enables seamless coordination of systems in the Agri-PV greenhouses, resulting in a measurable increase in crop yield and reduction in energy consumption. The greenhouse operators actively use the tool for daily operations and provide. They are reported with the necessary information to validate the operation of the plant.

Priority	5
Comments	Systems include smart Agri-PV systems, (biogas) thermal regulation, energy production, indoor parameters, and yield, among others.
	The operator must be educated and biologically/agriculturally trained to recognize smallest changes in plants.
Author	Diego Garcia (ETRA)

Requirement ID	K4_011
Description	[UC BG.02] The tool must incorporate biogas production models that allow different analysis on the technology.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	These analyses are the goal of the UC and models are needed in order to evaluate them and extract conclusions.
Acceptance criteria	The operator is able to select a model, enter the specific parameters of the analysis, and obtain the expected results.
Priority	5
Comments	Analyses include the use of different feedstock (including waste types from agriculture, forestry, lakes and rivers and other organic wastes in the area), the influence of pesticides, the effect on the soil of biproduct fertilizers, and the use of different biogas storage technologies.
Author	Diego Garcia (ETRA)

Requirement ID	K4_014
Description	[UC ES.02] The system shall integrate a KPI monitoring module to continuously assess and analyse KPIs.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements

Rationale	The implementation of KPI monitoring is essential for evaluation and optimization.
Acceptance criteria	The system must support the definition and customization of the KPIs.
Priority	5
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K4_015
Description	[UC ES.01] The system shall include capabilities to monitor and analyse how diffuse radiation from solar PV panels affects crop production.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	Understanding the specific effects of diffuse radiation on crops is crucial for optimizing cultivation strategies.
Acceptance criteria	The system provides quantitative data on the effects of diffuse radiation levels on crop production, contributing insights for improved agricultural planning.
Priority	3
Comments	
Author	Kevin Rodriguez (INDEREN)

Requirement ID	K4_016
Description	[Global] The DDS should be easy to use by the different types of users.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Usability and humanity requirements
Rationale	The tool should be accessible to different type of users with different background.

Acceptance criteria	Every type of users, and specially farmers and foresters should be easily capable to use most of the at least basic functionalities of the tool.
Priority	4
Comments	If needed a user manual should be provided together with the tool.
Author	Lola Alacreu (ETRA)

Requirement ID	**K4_017**
Description	[UC EE.01] The tool must model the wood ash recycling process to provide an estimation of GHG reduction.
Classification	KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Type	Functional and data requirements
Rationale	The reduction of GHG is a goal of the UC and it needs to be estimated for subsequent evaluation.
Acceptance criteria	The tool provides an interactive model of the wood ash recycling process and periodically estimates the reduction of GHG based on the data acquired.
Priority	4
Comments	
Author	Diego Garcia (ETRA)

Requirement ID	**K5_001**
Description	[Global] Carbon calculator tool should be working on-line.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Functional and data requirements
Rationale	Open-access carbon calculator for landowners and companies to estimate the potential profit from CO_2 fixation in marginal lands from wood production and carbon credit.

Acceptance criteria	Carbon calculator should be working on-line without failures.
Priority	5
Comments	
Author	Katri Ots (EULS)

Requirement ID	K5_002
Description	[UC EE.02] The carbon calculator tool must integrate the pilot sites of Spain, Bulgaria and Slovenia.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Functional and data requirements
Rationale	Expanding the usage of carbon calculator over Europe. Other pilot sites from the consortium will be integrated to the carbon calculator tools. Project partners will provide growth and yield models for the main tree species from Spain, Bulgaria and Slovenia.
Acceptance criteria	Up to date growth and yield models will be obtained from other pilot regions and included to the platform.
Priority	5
Comments	The pilot version of carbon calculator will be launched for Estonian conditions. The second stage of the platform development includes growth and yield models from other pilot sites.
Author	Reimo Lutter (EULS)

Requirement ID	K5_003
Description	[UC EE.02] Carbon calculator for landowners and companies should estimate the potential profit from CO_2 fixation in marginal lands from wood production and carbon credit.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Functional and data requirements

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Rationale	Carbon calculator tool as an open access product for landowners and companies to estimate the potentially avoided GHG emissions.
	The higher the carbon sequestration into biomass and biomaterial production, the greater is the potential to replace fossil-based products and lower the GHG emissions.
Acceptance criteria	Carbon calculator tool with GHG emissions describes avoided GHG emissions.
Priority	5
Comments	
Author	Katri Ots (EULS)

Requirement ID	K5_004
Description	[Global] The tool should operate without collecting, storing or transmitting any personal data or user inputs.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Functional and data requirements
Rationale	The user data is not collected to enhance user privacy. The computational models are not accessible to the users to protect intellectual property.
Acceptance criteria	The application does not request, collect, or store personal data or user inputs. The applications operational logic related to the computational models runs in a secure, server-side environment that users cannot access directly.
Priority	5
Comments	The initial or demo version of carbon calculator is a non-profit tool that does not require user registration.
Author	Katri Ots (EULS)

Requirement ID	K5_005
Description	[Global] The carbon sequestration tool should be easy to use by the different types of users.

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Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Usability and humanity requirements
Rationale	The tool should be accessible to users with various backgrounds.
Acceptance criteria	All types of users, especially farmers and foresters, should be able to easily use most, if not all, basic functionalities of the tool.
Priority	4
Comments	If necessary, a user manual should be provided alongside the tool.
Author	Lola Alacreu (ETRA)

Requirement ID	K5_006
Description	[Global] Carbon calculator tool does not require user registration.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Type	Usability and humanity requirements
Rationale	Open-access carbon calculator tool will not manage sensitive information and should be public accessed by unauthorized users.
Acceptance criteria	Users are not required to provide valid credentials to access the tool.
Priority	5
Comments	
Author	Katri Ots (EULS)

Requirement ID	K5_007
Description	[UC EE.04] The potential wood production of different deciduous tree species on different soil types must be monitored and modelled in Estonian conditions.
Classification	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols

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Type	Functional and data requirements
Rationale	Based on tree species and soil type the yield of forest plantation during the whole rotation cycle can be estimated.
Acceptance criteria	Have been created growth and yield models with adequate goodness-of-fit.
Priority	5
Comments	
Author	Katri Ots (EULS)

Requirement ID	K6_003
Description	[UC SI.06] Implement a feedback mechanism for farmers and foresters to report on the usability of biogas technologies.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Usability and humanity requirements
Rationale	Collect user experience data to improve the design and support for biogas technology.
Acceptance criteria	At least 80% of users should report satisfaction with the feedback process, and actionable improvements should be identified.
Priority	3
Comments	
Author	Zan Mongus (KIS)

Requirement ID	K6_004
Description	[UC SI.03] For CHP modular unit design, the end customer must have historical data on thermal and electric consumption to properly size the CHP system.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	The client, the customer and other stakeholders

Rationale	The potential customers and Buyers must have an overview over their actual consumption of electrical and thermal power to dimension the modular CHP unit tailor to their needs.
Acceptance criteria	The customers have historical data of at least one year in order to estimate their thermal and electric needs.
Priority	4
Comments	
Author	Jernej Zupancic (IRI UL)

Requirement ID	K6_005
Description	[UC SI.03] [UC SI.06] An overview of existing financing practices and schemes will be collected and provided to: interested local communities and investors.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Maintainability and support requirements
Rationale	An overview of financing options, including tailored options for specific countries, innovative funding methods like crowdfunding, and detailed real-world illustrations, including relevant links and contacts will serve as a guideline for new investments to accelerate community investments in innovative RES use. An overview of existing financing practices and schemes will be collected and presented/provided to: technology providers and interested local communities and investors.
Acceptance criteria	Collection of existing RES investments in rural area and farms for participating countries will be prepared.
Priority	4
Comments	
Author	Jernej Zupancic (IRI UL)

Requirement ID	K6_006
Description	[Global] Detailed economic cost breakdown with potential funding mechanisms will provide insights to end users and investors on the required RES investments in new innovative BMs.

Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Maintainability and support requirements
Rationale	Based on the financing schemes, interest rates, subsidies and technology cost, an economic overview indicates how much funding can be gained through support mechanism and what would end users need to invest.
Acceptance criteria	All required financial information is gathered in order to provide economic overview for new investments.
Priority	5
Comments	
Author	Jernej Zupancic (IRI UL)

Requirement ID	K6_007
Description	[UC BG.01] It needs to be analysed how Governments can economically support farmers, who install RES in combinations with or without back-up batteries.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Cultural and political requirements
Rationale	RES and especially batteries are a significant investment and enable greenhouse owners to run the greenhouses more, than 12 hours per day and to optimize the life cycles of the crop and harvest more, than once a year. The combination of PV and batteries allow more growing cycles per anno, without depending on price fluctuations of local utilities. Renewable energies stabilize the rural grid.
Acceptance criteria	Tax reduction programmes or subventions for farmers, who invest to stabilize the utility grid.
Priority	5
Comments	Similar programmes have been developed and are in the realization phase.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	K6_008

Description	[UC BG.03] An analysis must be done in order to assess and provide insights on national and European regulations impacting the integration of Agri-PV combined with Biogas solutions.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Functional and data requirements
Rationale	Understanding the complex environmental regulations is crucial for the successful implementation of Agri-PV in combination with biogas solutions. Comprehensive analysis can significantly aid in identifying viable BMs and regulatory pathways that lead to significant growth in renewable energies in rural regions.
Acceptance criteria	The analysis must be able to provide important information related to relevant local and European energy, agriculture, and environmental regulations.
Priority	5
Comments	When we focus on photovoltaics and biogas, it should not exclude other RES, like wind energy, active and passive solar energy or geothermal energy.
Author	Kai Vogelhaupt (ALBENA)

Requirement ID	K6_009
Description	[UC ES.05] Contracts should be drawn up for the transfer of the biofertilizer validation plots by the farmers.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Legal requirements
Rationale	The various parameters and performance protocols should be set out in a signed contract between the farmers involved and the consortium in order to ensure that the agreed commitments are met.
Acceptance criteria	Contracts should be written and accepted.
Priority	4
Comments	
Author	Bárbara Carreras (AVA-ASAJA)

Requirement ID	K6_011
Description	[UC EE.02] The efficiency of the biorefinery production must be possible to assess on the basis of the feedstock properties of woody biomass from novel short-rotation forest plantations.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Functional and data requirements
Rationale	Industrial scale testing of 4 wood species from novel short-rotation forest plantations and chemical analysis novel biomaterials have been processed. To be able to evaluate the production efficiency due to changes in feedstock properties compared to base case scenario.
Acceptance criteria	No adverse effects from feedstock changes (no reduced product quality, similar or better product output proportions, no increased challenges in pre-treatment due to changes in mechanical properties).
Priority	5
Comments	Industrial scale testing of 4 wood species and their genotypes from novel short-rotation forest plantations. Changes in macro chemical composition (different proportions of cellulose, hemicellulose and lignin) influence the proportion of each product from the biorefinery and therefore overall profitability. Changes in micro chemical composition, such as composition of different heavy metals may have an effect on each product quality. For example, abnormally high levels of heavy metals would limit some application areas. Changes in mechanical properties influence the processing capability of different feedstock and therefore influence overall cost-effectiveness.
Author	Katri Ots (EULS)

Requirement ID	K6_012
Description	[UC BG.03] TRU must develop a set of successful description of cooperative BMs and subsidy framework.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Maintainability and support requirements

Rationale	Analyse and evaluate practices facilitating the co-creation and assessment of cooperative BMs, subsidy proposals, and financial incentive structures among farmers, local stakeholders, and policymakers.
Acceptance criteria	Host a local workshop/seminar to encourage community participation and foster a collaborative approach in designing effective cooperative models and support mechanisms.
Priority	4
Comments	
Author	Konstantin Stoyanov (TRU)

Requirement ID	K6_013
Description	[UC BG.03] Renewable energy cooperatives shall promote their innovative approach (logo, slogan, common brand).
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	The client, the customer and other stakeholders
Rationale	The visibility and appeal of renewable energy cooperatives should be enhanced highlighting their ecological sustainability and social cooperation aspects. Thus, collaborative discussions shall be organised between researchers, cooperatives, associations and policymakers to align on optimal community models, branding approaches and financial support frameworks.
Acceptance criteria	Develop branding guidelines for renewable energy cooperatives.
Priority	4
Comments	
Author	Konstantin Stoyanov (TRU)

Requirement ID	K6_014
Description	[UC BG.03] TRU must prepare a showcase of modular renewable energy technologies suitable for small-scale agricultural cooperatives.

Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Maintainability and support requirements
Rationale	A detailed analysis on existing practices should be developed to provide comprehensive information on various modular technologies (e.g., biogas, biomass refinery, slow pyrolysis) and their suitability for different agricultural processes. It should provide information on cooperative requirements and recommend optimal technology combinations to ensure that cooperatives select the most appropriate renewable energy solutions based on their specific needs and resource availability.
Acceptance criteria	Host a local workshop/seminar to encourage community participation and foster a collaborative approach in designing effective cooperative models.
Priority	4
Comments	
Author	Konstantin Stoyanov (TRU)

Requirement ID	K6_015
Description	[UC BG.03] [UC SI.06] The project must align with existing agricultural and energy policies, and any efforts to redesign subsidies or introduce new BMs must be compliant with current legal frameworks.
Classification	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Type	Legal requirements
Rationale	Ensuring that new subsidies and BMs comply with the law is essential for their legitimacy and effectiveness.
Acceptance criteria	Verification through legal consultations and reviews to ensure that all proposed models and subsidies meet regulatory standards and policies.
Priority	5
Comments	Changes to legislation or the introduction of new regulations can be a lengthy process, often extending beyond the duration of typical project cycles. Stakeholder consultations, legislative procedures, and regulatory approvals can delay the implementation of legal changes. Therefore, it's important to manage expectations regarding the timing of any legal adaptations proposed during the project.

Author	Zan Mongus (KIS)

Requirement ID	K7_001
Description	[Global] Living Labs must integrate the stakeholders in the pilot area.
Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	The client, the customer and other stakeholders
Rationale	The opinion of all stakeholders involved is the key to the start-up and operation of the living lab.
Acceptance criteria	There must be at least one representative from each of the following areas: farmers, researchers, managers, cooperatives, agricultural companies, end consumer, or local community.
Priority	5
Comments	
Author	UPV_ECOLOOP

Requirement ID	K7_002
Description	[Global] If farmers with plots are not available, then the living lab will not be able to present experimental results.
Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	Users of the product
Rationale	The living lab must have farmers to apply the products in their fields.
Acceptance criteria	There must be at least five farmers.
Priority	5
Comments	
Author	UPV

Requirement ID	K7_003
Description	[Global] If there are many interested actors within an area, then selection criteria must be established.
Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	Functional and data requirements
Rationale	From the functional and data management point of view, it is necessary to work with groups of less than 40 information sources.
Acceptance criteria	The criteria of proximity, priority crops and extension of the crop area will be key to jointly select a maximum of 40 stakeholders from all areas.
Priority	5
Comments	
Author	UPV_ECOLOOP

Requirement ID	K7_004
Description	[UC ES.04] [UC ES.05] The bioproducts generated must improve soil quality.
Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	The purpose of the product
Rationale	Bioproducts can improve other agronomic/forestry properties, but the goal of the Soil LL is to improve soil quality.
Acceptance criteria	Bioproducts should modify (improve) two soil indicators as minimum.
Priority	4
Comments	
Author	UPV_ECOLOOP

Requirement ID	K7_005
Description	[Global] Soils must be monitored after the application of the bioproducts and strategies decided within the living lab activities in order to know their substantial improvement.

Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	Operational requirements
Rationale	If there is an improvement in soil health, this must be monitored and quantified by means of an analysis report.
Acceptance criteria	At least 3 soil analysis reports must be established: before the application, during the development and at the end.
Priority	5
Comments	
Author	UPV_ECOLOOP

Requirement ID	K7_006
Description	[Global] The participation of many stakeholders in the living lab is key, and therefore, their satisfaction must be evaluated because the design of the activities must be carried out to facilitate a friendly, dynamic and potential work environment.
Classification	KER 7: ECOLOOP-SOIL Living Lab
Type	Users of the product
Rationale	If the activities and work environment are pleasant, stakeholders can feel comfortable and express their opinions about soil health without coercion or guidelines.
Acceptance criteria	The satisfaction results of the group activities developed will show that more than 40% of the participants feel comfortable in the activity.
Priority	5
Comments	
Author	UPV_ECOLOOP

Requirement ID	K7_007
Description	[Global] The living lab is a space for generating and co-creating innovations, and results must be transferred to society.
Classification	KER 7: ECOLOOP-SOIL Living Lab

Type	The purpose of the product
Rationale	If the results generated are not transferred to society, the objective of the living lab has not been met.
Acceptance criteria	At a minimum, a workshop of result presentation must be held to transmit to society the results generated in the Living Lab.
Priority	5
Comments	
Author	UPV_ECOLOOP

11. Annex IV: KPIs

KPI ID	KPI_GA_01
KPI Name	Increase in Utilization of Local Zero- or Low-Carbon Energy Sources
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process KER 2: Optimal Combination of different renewable energy technologies to address the needs of agricultural or forest processes KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Related Use Case	UC BG.01: Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	This KPI measures the percentage increase in the utilization of local RES, such as solar (Agri-PV) and biogas, within Bulgarian pilot site operations, compared to the baseline year.
KPI Formula	$$\frac{RECconscur - REConsbase}{REConsbase} x100 = \left[\frac{1}{\%}\right]$$

Variables explanation	REConscur: Renewable Energy Consumption for current year/period - The total amount of energy consumed from local renewable sources in the current year/period (MWh)
	REConbase: Renewable Energy Consumption for baseline year/period - The total amount of energy consumed from local renewable sources in the baseline year/period (MWh)
	REInc: Increase in Utilization of Local Zero- or Low-Carbon Energy Sources in percentage
Unit of measurement	Percentage (%)
Baseline	The total renewable energy consumption at pilot site during the baseline year/period.
Target / Thresholds	Achieve a minimum of 5% increase in the utilization of local RES within 2 years of implementing Agri-PV systems and biogas solutions per the project plan.
Other comments	The successful increase in the utilization of RES will contribute to ALBENA's long-term sustainability goals and reduce dependency on non-RES.

KPI_GA_01 calculation	Description	Responsible
STEP 1	Calculate the total renewable energy consumed during the baseline year/period to establish the baseline.	ALBENA
STEP 2	Implement Agri-PV systems and biogas optimization operations as per the project plan.	ALBENA
STEP 3	Calculate the total renewable energy consumed at the Bulgarian pilot site in the current year after the implementation of renewable energy solutions.	ALBENA
STEP 4	Use the KPI formula to calculate the percentage increase in the utilization of local RES.	ALBENA

KPI ID	KPI_GA_02
KPI Name	Reduction of GHG emissions
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand

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Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
	KER 2: Optimal combination of different renewable energy technologies
Related Use Case	UC BG.01: Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes
	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	This KPI measures the percentage reduction in GHG emissions at Bulgarian pilot's site operations, attributable to the adoption of RES and energy efficiency improvements, compared to a baseline year.
KPI Formula	$$\frac{GHGbase - GHGcur}{GHGbase} x100 = \frac{1}{\%} RedGHG$$
Variables explanation	GHGbase: Total GHG emissions from operations during the baseline year or period (measured in CO2-equivalent units)
	GHGcur: Total GHG emissions from operations in the current year or period (measured in CO2-equivalent units)
	RedGHG: Reduction in GHG emissions measured in percentage
Unit of measurement	Percentage (%)
Baseline	The total GHG emissions from the Bulgarian pilot site during the baseline year/period.
Target Thresholds	Achieve a minimum of 50% reduction in GHG emissions within 3 years of implementing Smart Agri-PV and optimized biogas procedures.
Other comments	This KPI is critical for monitoring Bulgarian pilot site's progress towards its environmental sustainability goals, particularly in the context of climate change mitigation.

KPI_GA_02 calculation	Description	Responsible
STEP 1	Determine the total GHG emissions from the Bulgarian pilot site during the baseline period to establish the baseline.	ALBENA

STEP 2	Implement the planned renewable energy and energy efficiency projects, such as the Smart Agri-PV systems and biogas production enhancements.	ALBENA
STEP 3	Calculate the total GHG emissions from the Bulgarian pilot site in the current period after the implementation of the projects.	ALBENA
STEP 4	Use the KPI formula to calculate the percentage reduction in GHG emissions.	ALBENA

KPI ID	KPI_GA_03
KPI Name	Increase in Share of Renewables in Energy Mix
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Related Use Case	UC BG.01: Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	This KPI measures the percentage increase in the proportion of renewable energy (solar and biogas) in the total energy mix at the Bulgarian pilot site operations, compared to a baseline period.
KPI Formula	$$\frac{RECcur}{TECcur} - \frac{RECbase}{TECbase} x100 = \frac{1}{\%}IncrRS$$
Variables explanation	RECcur: Renewable Energy Consumption - The amount of energy consumed from renewable sources in the current year/period (MWh) TECcur: Total Energy Consumption - The total amount of energy consumed in the current period (MWh)

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RECbase: Renewable Energy Consumption - The amount of energy consumed from renewable sources in the baseline year/period (MWh)

TECcur: Total Energy Consumption - The total amount of energy consumed in the baseline period/year (MWh)

IncrRS: Increase of renewable share in percentage

Unit of measurement	Percentage point increase (%)
Baseline	The proportion of renewable energy in the total energy mix during the baseline period.
Target Thresholds	Achieve a minimum 25 percent increase in the share of renewable energy within the total energy mix by the end of the project's period.
Other comments	This KPI is vital for tracking Bulgarian pilot site's progress towards a greener energy mix and aligns with global renewable energy adoption targets.

KPI_GA_03 calculation	Description	Responsible
STEP 1	Calculate the proportion of renewable energy in the total energy mix during the baseline period to establish the baseline.	ALBENA
STEP 2	Implement renewable energy projects, such as the expansion of Smart Agri-PV systems and enhancements in biogas production.	ALBENA
STEP 3	Calculate the proportion of renewable energy in the total energy mix in the current period after the implementation of renewable energy projects.	ALBENA
STEP 4	Use the KPI formula to calculate the percentage point increase in the share of renewable energy within the total energy mix.	ALBENA

KPI ID	KPI_GA_4
KPI Name	Increase of distributed RES capacity of the project pilot sites

Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Related Use Case	UC ES.01: An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops
Responsible	INDEREN
KPI Description	This KPI presents the increase in % (or kW) of the amount of distributed RES compared to the totally distributed RES in the business-as-usual situation.
KPI Formula	$$\mathrm{RES}_{\mathrm{capacity}} = \frac{P_{RES,PR} - P_{RES,BaU}}{P_{RES,BaU}} \times 100$$
Variables explanation	$\mathrm{RES}_{\mathrm{capacity}}$ [%]: Increase of the distributed RES capacity of the project pilot site
	$P_{RES,PR}$: Total power from RES during the project
	$P_{RES,BaU}$: Total power from RES in the business-as-usual scenario
Unit of measurement	Percentage in %
Baseline	This depends on the amount of kW installed Renewable Energy at the Start of the testing period. Assumption is 0.
Target / Thresholds	At least 10-30%
Other comments	

KPI_GA_04 calculation	Description	Responsible
STEP 1	Measure and record the total power from distributed RES in the business-as-usual (BaU) scenario. This is the RES capacity that would exist without any project interventions. The assumption here is 0 kW if no RES capacity is installed at the start of the project.	INDEREN
STEP 2	Measure and record the total power from distributed RES during the project implementation.	INDEREN
STEP 3	Use the KPI formula to calculate the percentage increase in RES capacity	INDEREN

KPI ID	KPI_GA_05
KPI Name	Reduction of energy costs in Bulgarian pilot site.
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC BG.01: Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes
Responsible	ALBENA
KPI Description	This KPI measures the percentage reduction of energy costs during the project period, due to increase of renewable energy (solar and biogas) in the total energy mix at the Bulgarian pilot site operations, compared to a baseline period.
KPI Formula	$$CredEn\frac{1}{\%} = \left(\frac{CEnBase}{ConsEnBase} - \frac{CEnCurr}{ConsEnCurr}\right)x100$$
Variables explanation	CredEn: Cost reduction in %, related to the period before implementing RES on the pilot site
	CEnBase: Total Energy Cost before implementing RES
	ConsEnBase: Total energy consumption before implementing RES
	CEnCurr: Total Energy Cost before after implementing RES
	ConsEnCurr: Total energy consumption after implementing RES
Unit of measurement	Percentage point deduction (%)
Baseline	The average amount of costs/consumed MWh during the baseline year.
Target / Thresholds	Achieve a minimum 30 percent decrease in energy costs on the pilot site during the project period.
Other comments	This KPI is vital for tracking Bulgarian pilot site's progress towards a greener energy mix, while reducing costs at the same time.

KPI_GA_05 calculation	Description	Responsible

STEP 1	Calculate and document the total consumption, as well as the costs for energy on the pilot site, during the baseline year.	ALBENA
STEP 2	Implement renewable energy projects, such as the expansion of Smart Agri-PV systems and enhancements in biogas production.	ALBENA
STEP 3	Calculate the consumption, as well as the costs for energy on the pilot site, during the current year.	ALBENA
STEP 4	Use the KPI formula to calculate the percentage point decrease in energy costs on the pilot site.	ALBENA

KPI ID	KPI_GA_06
KPI Name	Increase of energy self-consumption in rural areas
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC ES.01: An Agri-PV and geothermal energy community for sustainable introduction of sub-tropical and horticultural crops
Responsible	INDEREN
KPI Description	This KPI measures the percentage increase of energy self-consumption in rural areas during the project period, due to increase of renewable energy (solar and biogas) in the total energy mix at the Spanish pilot site, compared to a baseline period.
KPI Formula	$$E_{\text{self-consumption}} = \frac{E_{self-consumption,PR} - E_{self-consumption,BaU}}{E_{self-consumption,BaU}} \times 100$$
Variables explanation	$E_{\text{self-consumption}}$ [%]: Increase of energy self-consumption in rural areas $E_{self-consumption,PR}$: Energy self-consumption – only part consumed behind the metering point- during the project

	$E_{self-consumption,BaU}$: Energy self-consumption – only part consumed behind the metering point - in the business-as-usual scenario
Unit of measurement	Percentage in %
Baseline	The average amount of consumed MWh during the baseline year.
Target / Thresholds	Achieve a minimum 50 percent increase in energy costs on the pilot site during the project period.
Other comments	

KPI_GA_06 calculation	Description	Responsible
STEP 1	Calculate and document the total consumption on the pilot site, during the baseline year.	INDEREN
STEP 2	Implement renewable energy projects, such as the expansion of Smart Agri-PV systems and enhancements in biogas production.	INDEREN
STEP 3	Calculate the amount of energy generated by the renewable energy implementations on the pilot site, during the current year.	INDEREN
STEP 4	Use the KPI formula to calculate the Energy self-consumption on the pilot site.	INDEREN

KPI ID	KPI_ES_07
KPI Name	Reduction of waste generation in agriculture
Strategic Objective(s)	O2: To optimise agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
Related Use Case	UC ES.02: Biogas/Biomethane Production from Agricultural Waste
Responsible	AVA-ASAJA
KPI Description	This KPI measures the percentage of waste recovery from agriculture in the region. Aligned with the strategic objectives of reducing and reusing waste generated in the agricultural sector.

KPI Formula	The reduction of waste generation in agriculture is calculated as the percentage of reduced waste compared with the total waste generated, using the formula: $$\text{Reduction of waste generation in agriculture (\%)}$$ $$= \frac{Reused\ waste}{Total\ waste\ generated} \, x \, 100$$
Variables explanation	Reused waste: Amount of agricultural waste enhanced Total waste generated: the total amount of the waste generated by the suppliers
Unit of measurement	Percentage (%)
Baseline	Nowadays, the agricultural waste generated in the area, is not employed in the generation of renewable energies.
Target / Thresholds	The desired reduction of agricultural waste generation in the area should be around 20%.
Other comments	The aim of the research is finding alternative sources that increase the profitability of the agricultural waste; Hence the producers of this waste could get some economic and social benefits out of this process.

KPI_ES_07 calculation	Description	Responsible
STEP 1	Collect information regarding the amount of waste generated coming from the area´s producers.	AVA-ASAJA
STEP 2	Once the biogas plant is set up, calculate the agricultural waste used for the production of bioenergy and other biobased products (biogas, biomethane).	AVA-ASAJA
STEP 3	Calculate the amount of enhanced waste over the total amount of agricultural waste generated by the area´s producers.	AVA-ASAJA

KPI ID	KPI_GA_08
KPI Name	Increase in Recycling and Reuse Rate of Agricultural waste
Strategic Objective(s)	O2: To optimise agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater

Related Use Case	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	This KPI measures the percentage increase in the rate of recycling and reuse of waste materials (measured in tons) generated from agricultural and other activities at the Bulgarian pilot site's operations, compared to a baseline period.
KPI Formula	$$\frac{WRRcur - WRRbase}{WRRbase} x100 = \left[\frac{1}{\%}\right] Rec\ incr$$
Variables explanation	WRRcur: Waste Recycled and Reused current period - Total weight of waste (agri-waste, food waste, or waste generated from other activities) recycled and reused from agricultural and forest activities in the current period (tons) WRRbase: Waste Recycled and Reused baseline period - Total weight of waste (agri-waste, food waste, or waste generated from other activities) recycled and reused from agricultural and forest activities during the baseline period (tons) Rec incr.: Recycle rate increased, measured in percentage
Unit of measurement	Percentage point increase (%)
Baseline	The rate of recycling and reuse of waste generated, which includes agri-waste, food waste, or waste generated from other activities from agricultural activities during the baseline period.
Target / Thresholds	Achieve a 5% point increase in the rate of recycling and reuse within 2 years of implementing enhanced waste management and circular economy practices.
Other comments	This KPI will effectively measure Bulgarian pilot site's progress in improving waste management practices, promoting the recycling and reuse of materials, and contributing to the sustainability goals of the project and the broader objectives of the ECOLOOP project.

KPI_GA_08 calculation	Description	Responsible
STEP I	Calculate the rate of recycling and reuse of waste from agricultural and forest activities during the baseline period to establish the baseline.	ALBENA

STEP 2	Implement enhanced waste management practices, recycling programs, and initiatives for the reuse of organic and inorganic materials within agricultural and forestry operations.	ALBENA
STEP 3	Calculate the rate of recycling and reuse of waste from agricultural and forest activities in the current period after the implementation of enhanced practices.	ALBENA
STEP 4	Use the KPI formula to calculate the percentage point increase in the rate of recycling and reuse of agricultural waste.	ALBENA

KPI ID	KPI_GA_09
KPI Name	Increase of Profitability of Waste Generated in Agriculture and Forest Activities
Strategic Objective(s)	O2: To optimize agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
Related Use Case	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA, TRU
KPI Description	This KPI measures the increase in profitability derived from the management and conversion of agricultural and forest waste into valuable products such as bioenergy and biobased products. Currently, agricultural waste is not being utilized, resulting in zero profitability from this resource. The KPI will track the transition to incorporating agricultural waste into the biogas production process by comparing the costs of collecting and processing this waste with the profits generated from the resulting biogas. This transition is expected to enhance overall cost-effectiveness, highlighting both economic and environmental benefits."
KPI Formula	$$PI\,agri = \left(\frac{Pagri}{Cagri} - 1\right) x100$$

Variables explanation	Pagri: Profit per ton of agri-waste in terms of biogas produced
	Cagri: Cost per ton for collecting agri-waste
	PI agri: Profitability increase percentage of using agri-waste
Unit of measurement	Percentage (%)
Baseline	Baseline profit is 0 – The biogas facility does not work with agri-waste.
Target / Thresholds	Achieve a minimum 30% increase in profitability within the project duration.
Other comments	This KPI will help assess the financial viability and sustainability of the waste-to-energy processes implemented in the project.

KPI_GA_09 calculation	Description	Responsible
STEP 1	Conduct a thorough financial analysis of current waste management practices, including detailed records of revenues and costs. As agricultural waste is not currently being utilized, ensure that baseline profitability for agricultural waste is recorded as zero.	ALBENA
STEP 2	Estimate and Measure Costs: Calculate the projected costs for collecting and processing agricultural waste, including logistics, labour, and technology deployment costs.	ALBENA
STEP 3	Implement New Technologies and Processes: Deploy new technologies and processes for converting agricultural waste into biogas and other biobased products. Ensure proper integration with existing systems to optimize efficiency.	ALBENA
STEP 4	Monitor and Record Revenue: After implementation, monitor and record the revenue generated from selling biogas derived from both maize silage and the newly introduced agricultural waste.	ALBENA
STEP 5	Calculate Post-Implementation Costs: Calculate the actual costs incurred in the waste management and conversion processes post-implementation, ensuring these are categorized by waste type (maize silage and agricultural waste).	ALBENA

STEP 6	Apply the KPI Formula: Use the KPI formula to determine the percentage increase in profitability of the Agri Waste.	ALBENA

KPI ID	KPI_GA_10
KPI Name	Increase yield productivity using biofertilizers instead of chemical fertilizers
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater KER 7: ECOLOOP-SOIL Living Lab
Related Use Case	UC BG.01 Smart agricultural PV implementation in greenhouses and scale-up in combination with biogas energy for sustainable processes
Responsible	ALBENA, TRU
KPI Description	This KPI presents the yield raise as a number in percentage per m² Greenhouse area. This will be comparable to existing Greenhouses with chemical Fertilizers.
KPI Formula	Yield (raise) = Yield (bio fertilizer) / Yield (chemical fertilizers)
Variables explanation	Yield (raise) is the more / extra production by using Bio Fertilizers over the period of 1 year Yield (Bio Fertilizer) (for the same period) Yield (Chemical Fertilizer) (for the same period)
Unit of measurement	Growth of Yield in percentage
Baseline	The base or zero line is the yield per m² fertilized by chemical Fertilizer.
Target / Thresholds	For Greenhouses the long-term task has to be to eliminate chemical Fertilizers.
Other comments	This process will take several cycles, since farmers are often on the short leash of the fertilizer producers. It will take a legal framework by EU, to convince farmers, and maybe for a starting period financial motivation by the local governments either to the farmers, or to fertilizer manufacturer, while changing their production lines.

KPI_GA_10 calculation	Description	Responsible
STEP 1	Calculate the yield per m² Greenhouse, when using chemical Fertilizers. This also includes a cost calculation.	ALBENA, TRU
STEP 2	Prepare a Greenhouse for usage of only Bio Fertilizers. With otherwise same environment (to make results comparable.	ALBENA, TRU
STEP 3	Document growth of plants and taste and optics of fruits.	ALBENA, TRU
STEP 4	Evaluate results and describe efficiency and the potential additional yield due to not using chemical Fertilizer.	ALBENA, TRU

KPI ID	KPI_GA_011
KPI Name	Reduction in Groundwater Contamination Levels
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA, TRU
KPI Description	This KPI measures the percentage reduction in key groundwater contaminants measured at designated monitoring points within and adjacent to Bulgarian site's operations, compared to a baseline period.
KPI Formula	$$\frac{ContLevbase - Contlevcur}{ContLevbase} x100 = \left[\frac{1}{\%}\right] REDGCL$$
Variables explanation	ContLevBase: Contaminant Levels (baseline period): Concentration of key contaminants in groundwater during the baseline period (measured in mg/L or equivalent units) ContLevCur: Contaminant Levels (current period): Concentration of key contaminants in groundwater in the current period (measured in mg/L or equivalent units) REDGCL: Reduction in Groundwater Contamination Levels in percentage

Unit of measurement	Percentage (%)
Baseline	The concentration of key groundwater contaminants during the baseline period.
Target / Thresholds	Achieve a minimum of 10% reduction in the concentration of key groundwater contaminants within 2 years of implementing sustainable agricultural practices and waste management strategies.
Other comments	This KPI is essential for tracking the effectiveness of initiatives aimed at reducing the environmental impact of operations on groundwater quality.

KPI_GA_11 calculation	**Description**	**Responsible**
STEP 1	Establish baseline contaminant levels in groundwater by conducting comprehensive water quality testing at designated monitoring points.	ALBENA, TRU
STEP 2	Implement sustainable agricultural practices, improve waste management, and other measures aimed at reducing the potential for contaminant leaching into groundwater.	ALBENA, TRU
STEP 3	Conduct water quality testing at the same monitoring points in the current period to determine current contaminant levels.	ALBENA, TRU
STEP 4	Use the KPI formula to calculate the percentage reduction in groundwater contaminant levels.	ALBENA, TRU

KPI ID	**KPI_GA_012**
KPI Name	Reduce the cost of fertilizers
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC ES.03: Biofertilizers production from agricultural wastes
Responsible	FERTINAGRO

KPI Description	This KPI measures the cost reduction achieved by using digestate from the biogas plant in the production of new fertilizers instead of commercial products. It compares the cost of production using commercial products (baseline) to the cost using the digestate from the biogas plant.
KPI Formula	$$\text{Cost reduction (\%)} = \frac{Baseline\ Cost - Digestate\ cost}{Baseline\ Cost} \times 100$$
Variables explanation	Baseline Cost: The current cost of producing fertilizers using commercial products Digestate Cost: The cost of producing fertilizers using digestate from the biogas plant (assumed to be free of charge)
Unit of measurement	Percentage (%)
Baseline	The baseline cost is the actual current cost of producing the fertilizers using commercial products.
Target / Thresholds	Cost Reduction: Aim for at least a 15-20% reduction in production costs.
Other comments	

KPI_GA_12 calculation	Description	Responsible
STEP 1	Determine the current cost of producing fertilizers using commercial products. This should include all associated costs such as raw materials, labour, energy.	FERTINAGRO
STEP 2	Calculate the cost of producing fertilizers using the digestate from the biogas plant. Since the digestate is free of charge, this cost will only include processing, labour, energy,	FERTINAGRO
STEP 3	Use the formula to calculate the percentage reduction in production costs	FERTINAGRO

KPI ID	KPI_GA_13
KPI Name	Reduction in Chemical Fertilizer Use
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater

Related Use Case	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	This KPI measures the percentage reduction in the use of chemical fertilizers (measured in tons) within agricultural operations, compared to a baseline period.
KPI Formula	$$\frac{ChemFertUseBase - ChemFertUseCur}{ChemFertUseBase} x100 = \left[\frac{1}{\%}\right] RedChemF$$
Variables explanation	ChemFertUseBase: Chemical Fertilizer Use (baseline period) - The amount of chemical fertilizers used during the baseline period ChemFertUseCur: Chemical Fertilizer Use (current period) - The amount of chemical fertilizers used in the current period RedChemF: reduction of chemical fertilizer usage in percentage
Unit of measurement	Percentage (%)
Baseline	The amount of chemical fertilizers used during the baseline period.
Target / Thresholds	Achieve a minimum of 15% reduction in the use of chemical fertilizers within three years of implementing sustainable farming practices and biofertilizer adoption.
Other comments	This KPI is critical for assessing the shift towards more sustainable and environmentally friendly farming practices. It will effectively measure progress in reducing the use of chemical fertilizers, demonstrating commitment to sustainable farming practices according to the broader objectives of the ECOLOOP project.

KPI_GA_13 calculation	Description	Responsible
STEP 1	Determine the amount of chemical fertilizers used during the baseline period to establish the baseline.	ALBENA, TRU
STEP 2	Implement initiatives aimed at reducing chemical fertilizer use, such as the introduction of biofertilizers, improved soil health practices, and precision agriculture techniques.	ALBENA, TRU
STEP 3	Measure the amount of chemical fertilizers used in the current period after the implementation of these initiatives.	ALBENA, TRU
STEP 4	Use the KPI formula to calculate the percentage reduction in the use of chemical fertilizers.	ALBENA, TRU

KPI ID	KPI_GA_14
KPI Name	New jobs created in the pilot sites area
Strategic Objective(s)	None, project related
Related ECOLOOP innovation	None, project related
Related Use Case	None, project related
Responsible	Each Pilot site
KPI Description	This KPI measures the number of jobs created directly for ECOLOOP project
KPI Formula	Count of the number of jobs created.
Variables explanation	N/A - This KPI is a direct count
Unit of measurement	Number of people.
Baseline	The current number of people.
Target / Thresholds	Achieve at least one job created for each pilot site.
Other comments	

KPI_GA_14 calculation	Description	Responsible
STEP 1	Establish a baseline count of the people involved in the project.	All pilots
STEP 2	Count the jobs created by pilot site.	All pilots

KPI ID	KPI_GA_15
KPI Name	Identification and Analysis of Regulatory Barriers and Gaps and Analysis of Regulatory Barriers and Gaps
Strategic Objective(s)	O4: To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative BMs, financial instruments and policy recommendations

Related ECOLOOP innovation	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC BG.03: National and regional regulation and business model's implementation to foster rural development
Responsible	TRU
KPI Description	This KPI measures the total number of regulatory barriers and gaps identified and thoroughly analysed that impact the implementation of renewable energy solutions and sustainable practices s, with the aim of proposing actionable solutions or recommendations to address these challenges.
KPI Formula	Count of regulatory barriers and gaps identified and analysed.
Variables explanation	N/A - This KPI is a direct count
Unit of measurement	Number of identified and analysed barriers/gaps
Baseline	The number of regulatory barriers and gaps identified before the initiation of the ECOLOOP project (likely to be zero or a nominal figure).
Target / Thresholds	Identify and analyse at least 3 regulatory barriers and gaps by the end of the ECOLOOP project duration.
Other comments	The identification and analysis should be comprehensive, involving a review of local, regional, and national regulations and policies, and should lead to the development of strategies or recommendations to navigate or address these barriers.

KPI_GA_15 calculation	Description	Responsible
STEP 1	Establish a baseline count of identified regulatory barriers and gaps, if any, prior to the ECOLOOP project initiation.	TRU
STEP 2	Collaborate with legal experts, policy analysts, and stakeholders to conduct a thorough review of the regulatory landscape affecting the project's scope.	TRU
STEP 3	Document each regulatory barrier and gap identified during the review process, along with an in-depth analysis of its implications for the project.	TRU
STEP 4	Develop strategies, recommendations, or solutions to navigate or address the identified barriers and gaps.	TRU
STEP 5	Count the total number of regulatory barriers and gaps identified and analysed during the project period.	TRU

KPI ID	KPI_GA_16
KPI Name	Number of Policy Recommendations Provided
Strategic Objective(s)	O4: To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative BMs, financial instruments and policy recommendations
Related ECOLOOP innovation	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC BG.03: National and regional regulation and business model's implementation to foster rural development
Responsible	TRU
KPI Description	This KPI tracks the total number of comprehensive policy recommendations developed and provided to local, regional, or national policymakers, aimed at fostering rural development and the adoption of renewable energy solutions within the project's scope.
KPI Formula	Count of policy recommendations drafted and submitted to policymakers.
Variables explanation	N/A - This KPI is a direct count
Unit of measurement	Number of recommendations
Baseline	zero
Target / Thresholds	Develop and provide at least 3 comprehensive policy recommendations by the end of the ECOLOOP project duration.
Other comments	The identification and analysis should be comprehensive, involving a review of local, regional, and national regulations and policies, and should lead to the development of strategies or recommendations to navigate or address these barriers.

KPI_GA_16 calculation	Description	Responsible
STEP 1	Establish a baseline count of policy recommendations, if any, provided before the ECOLOOP project initiation.	TRU
STEP 2	Assemble a multidisciplinary team, including policy experts, researchers, and stakeholders, to identify key areas for policy intervention and improvement.	TRU

STEP 3	Conduct research and analysis to develop actionable policy recommendations that address identified areas.	TRU
STEP 4	Document and submit each policy recommendation to the relevant policymakers or bodies.	TRU
STEP 5	Count the total number of policy recommendations developed and provided during the project period.	TRU

KPI ID	KPI_ES_I
KPI Name	Vegetative development of plants
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem)
Related Use Case	UC ES.04 Enhancement of soil properties (agriculture-forestry) bioproducts validation UC ES.05 Tests of the behaviour of the product in agronomic application
Responsible	UPV
KPI Description	This indicator measures the improvement of the vegetative development of plants after the bioproduct application. Diameter, height, NDVI, or soil cover are variables to control de vegetative development
KPI Formula	$$Vegetal\ development\ difference = \frac{(VSf - VSi)}{(\frac{VSf + VSi}{2})} * 100$$
Variables explanation	VSf: Final value of vegetative state VSi: Initial value of vegetative state
Unit of measurement	%
Baseline	0%
Target / Thresholds	10-50%
Other comments	/

KPI_ES_I calculation	Description	Responsible
STEP I	Measurement of the vegetative state (diameter, NDVI, soil cover, height) in the field or laboratory before the bioproduct application.	UPV
STEP 2	Measurement of the vegetative state in the field or laboratory after the bioproduct application.	UPV
STEP 3	Calculation of the vegetative development difference.	UPV

KPI ID	KPI_ES_2
KPI Name	Soil quality indicator improvement
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater KER 4: Decision support tool for farmers and foresters (AI and big data analytics / IoT ecosystem) KER 7: ECOLOOP soil Living labs (LL)
Related Use Case	UC ES.04: Enhancement of soil properties (agriculture-forestry) bioproducts validation UC ES.05: Tests of the behaviour of the product in agronomic application
Responsible	UPV
KPI Description	This indicator measures the improvement of soil properties considered as quality indicators (SQI), evaluating their increase. The SQI will be treated individually, with the variables to be calculated: organic matter, aggregate stability, total nitrogen, soil respiration, etc.
KPI Formula	$$SQI\ difference = \frac{(SQIf - SQIi)}{(\frac{SQIf + SQIi}{2})} * 100$$
Variables explanation	SQIf: Final value of soil quality indicator at the end of the project SQIi: Initial value of soil quality indicator
Unit of measurement	%

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Baseline	0%
Target / Thresholds	10-50%
Other comments	

KPI_ES_2 calculation	Description	Responsible
STEP 1	Measurement of indicators in the field or laboratory before the bioproduct application.	UPV
STEP 2	Measurement of SQI in the field or laboratory after the bioproduct application.	UPV
STEP 3	Calculation of the SQI difference.	UPV

KPI ID	KPI _ES_3
KPI Name	Increase of biogas production in rural areas
Strategic Objective(s)	O2: To optimize agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 1: Efficient biogas production and conversion process
Related Use Case	UC ES.02: Biogas/biomethane production from agricultural wastes
Responsible	GENIA
KPI Description	This indicator measures the efficiency of biogas production from agricultural wastes, evaluating the volume of biogas generated.
KPI Formula	$Biogas\ Production\ Efficiency: \dfrac{Volume\ of\ Biogas\ generated}{Total\ agricultural\ waste\ input}\ x\ 100$
Variables explanation	Volume of Biogas Generated: The total amount of biogas produced in the system Total Agricultural Waste Input: The cumulative quantity of agricultural waste processed in the system
Unit of measurement	Percentage (15%)
Baseline	0 %

Target / Thresholds	Biogas production efficiency: 50-70%
Other comments	The KPI aims to assess the effectiveness of the biogas production process in utilizing agricultural wastes, contributing to waste reduction and sustainable agricultural practices.

KPI_ES_3 calculation	Description	Responsible
STEP 1	Measurement of biogas produced in the pilot plant.	GENIA, INDEREN
STEP 2	Measurement of the total amount of waste introduced into the anaerobic digester.	GENIA, INDEREN
STEP 3	Calculation of biogas production efficiency by dividing the amount of biogas generated by the amount of waste introduced.	GENIA, INDEREN

KPI ID	KPI_ES_4
KPI Name	Digestate Transformation
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC ES.03: Biofertilizers production from agricultural wastes
Responsible	FERTINAGRO
KPI Description	This indicator measures the capacity to transform the digestate generated in the production of biogas into biofertilizers.
KPI Formula	$Digestate\ Transformation\ Efficiency = \frac{Total\ digestate\ transformed}{Total\ digestate\ produced} * 100$
Variables explanation	Total Digestate Transformed: The total amount of digestate used to produce the biofertilizer Total Digestate Produced: The total amount of digestate produced by the biogas plant
Unit of measurement	Percentage (%)
Baseline	0%

Target / Thresholds	90-100%
Other comments	

KPI_ES_4 calculation	Description	Responsible
STEP 1	Measurement of digestate produced in the pilot plant.	INDEREN, GENIA
STEP 2	Measurement of the total amount of digestate transformed into fertilizer.	FERTINAGRO
STEP 3	Calculation of digestate transformation efficiency by dividing the amount of digestate transformed by the amount of digestate produced.	FERTINAGRO

KPI ID	KPI_ES_5
KPI Name	Digestate ratio in biofertilizer
Strategic Objective(s)	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC ES.03: Biofertilizers production from agricultural wastes
Responsible	FERTINAGRO
KPI Description	This indicator measures the proportion of digestate in the biofertilizer manufactured from the digestate produced in the biogas plant.
KPI Formula	$$Digestate\ ratio = \frac{Total\ digestate\ included}{Total\ biofertilizer\ produced} * 100$$
Variables explanation	Total Digestate Included: The total amount of digestate used to produce the biofertilizer Total Biofertilizer Produced: The total amount of biofertilizer produced from the digestate
Unit of measurement	Percentage (%)
Baseline	0%

Target / Thresholds	The digestate will primarily consist of water, comprising at least 70% of the resulting biofertilizer. This high-water content will ensure that the added nutrients are more concentrated within the biofertilizer.
Other comments	

KPI_ES_5 calculation	Description	Responsible
STEP 1	Measurement of the total amount of digestate included into the fertilizer.	FERTINAGRO
STEP 2	Measurement of the total amount of fertilizer produced.	FERTINAGRO
STEP 3	Calculation of digestate ratio by dividing the amount of digestate included into the fertilizer by the amount of fertilizer produced.	FERTINAGRO

KPI ID	KPI_BG_1
KPI Name	Percentage Increase in Biogas Production from Agri-Waste
Strategic Objective(s)	O2: To optimise agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
Related Use Case	UC BG.02: Regional agricultural and other waste analysis and potential biogas production
Responsible	ALBENA
KPI Description	Measures the increase in % biogas production resulting from the optimized processing of agricultural and other organic wastes.
KPI Formula	$$BP_{inc}\left[\frac{1}{\%}\right] = \frac{BPpostimpl - BPpreimpl}{BPpreimpl}x100$$
Variables explanation	BPpostimpl: Biogas production post implementation - Total biogas production after implementing new technologies and processes, measured in m^3/a Total biogas production before optimization

	BPpreimpl: Biogas production pre-implementation - Total biogas production before optimization; measured in m^3/year
	BPinc: Biogas production increase in percentage
Unit of measurement	m³/year
	Percentage increase
Baseline	Pre-optimization biogas production levels.
Target / Thresholds	Achieve a minimum of 5% increase within 1 year of implementing optimizations.
Other comments	This KPI aims to quantify the effectiveness of new biogas production technologies and processes introduced by the ECOLOOP project.

KPI_BG_1 calculation	Description	Responsible
STEP 1	Measure the total biogas production before optimization.	ALBENA
STEP 2	Implement new technologies and processes for biogas production.	ALBENA
STEP 3	Measure the total biogas production after optimization.	ALBENA
STEP 4	Calculate the percentage increase in biogas production.	ALBENA

KPI ID	KPI_SI_01
KPI Name	Data collection reliability
Strategic Objective(s)	O1: To promote the penetration of decentralized renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1.1: Flexibility management to increase the profitability of the slow pyrolysis process
	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Related Use Case	UC SI.01 Optimize the operation and improve the security of supply of biomass centre Nazarje

	UC SI.02 Utilization of flexibility of the biomass centre Nazarje
Responsible	SETUP, BIOMASA
KPI Description	Data collection reliability quantifies the proportion of measurement data successfully received within a specified time frame (typically 15 minutes). This metric serves as an indicator of the robustness of the data connection, offering insights into the aggregator's proficiency in executing aggregation and operational optimization algorithms effectively.
KPI Formula	$$DR = \frac{N_{Measurement\_ok}}{N_{total}} \times 100\%$$
Variables explanation	DR [%]: Data reliability $N_{Measurement\_ok}$: The count of intervals during which measurement data packets were received successfully N_{total}: The total count of specified time intervals within the observed period (e.g., 4 intervals for one hour)
Unit of measurement	Percentage in %
Baseline	Flexibility assets are not integrated with the aggregator platform. Therefore, the baseline cannot be defined.
Target / Thresholds	95%
Other comments	/

KPI_SI_01 calculation	Description	Responsible
STEP 1	The aggregator defines the observation period and calculates the number of measurements, that should be received.	SETUP, BIOMASA
STEP 2	The aggregator inspects how many measurements were not received or were invalid.	SETUP, BIOMASA
STEP 3	The aggregator calculates the KPI.	SETUP, BIOMASA

KPI ID	KPI_SI_2
KPI Name	Potential Growth in Stakeholder Engagement

Strategic Objective(s)	O4: To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative BMs, financial instruments and policy recommendations
Related ECOLOOP Innovation	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC SI.06 Redesign of subsidies and new BMs for biogas
Responsible	KIS, UL
KPI Description	Measures change in stakeholder interest in biogas and biomethane technologies post-presentations.
KPI Formula	Engagement Growth (%) = ((Post - Pre) / Pre) x 100 $$E_i = \frac{E_{final} - E_{initial}}{E_{initial}} * 100\%$$
Variables Explanation	Pre-survey Score: Initial interest level from surveys before presentations Post-survey Score: Interest level from surveys after presentations
Unit of Measurement	Percentage of interested stakeholders (%)
Baseline	Established from pre-presentation survey scores.
Target / Thresholds	Aim for a 25% increase in engagement post-presentations.
Other comments	Surveys should be designed to accurately gauge interest, understanding, and willingness to engage in biogas initiatives.

KPI_SI_2 calculation	Description	Responsible
STEP 1	Conduct pre-presentation surveys to establish baseline interest.	KIS, UL
STEP 2	Conduct post-presentation surveys to measure engagement growth.	KIS, UL
STEP 3	Calculate the rise in interest and potential disinterest for implementing biogas plants into their community.	KIS, UL

KPI ID	KPI_SI_3

KPI Name	Biomethane production rate
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand O2: To optimise agricultural/forest waste management reducing the associated emissions
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process
Related Use Case	UC SI.05 Biomethane from biogas power plant utilization for agricultural machinery
Responsible	KIS, UL
KPI Description	This KPI measures the daily production rate of biomethane at the biogas power plant.
KPI Formula	$$Biomethane\ production\ rate\ (Sm^3/day)$$ $$= Total\ volume\ of\ biomethane\ produced\ /\ Number\ of\ days$$
Variables explanation	Total volume of biomethane produced: the cumulative volume of biomethane produced in a specific period. Integrated electronic measurement system, presented biogas and biomethane production in Nm3/h or Sm3/h. The first unit of the biogas plant produces biogas from processed biomass, the second added upgrade will add a gas cleaning unit for biomethane production. Number of days: The duration in days for which the production is measured
Unit of measurement	Standard cubic meters of biogas produced in anaerobic digestion per day (Sm³/day), standard cubic meters of biomethane processed (cleaning and upgrading of biogas) per day (Sm³/day) in fixed temperature and pressure.
Baseline	30 Sm³ biogas/day and after cleaning and upgrading biogas to biomethane, 15-20 Sm³ biomethane/day. Conversion from biogas to biomethane is approx. 60%.
Target / Thresholds	5-10% increase in biogas and biomethane production with adding additionally mechanically processed biomass for higher recovery of methane in anaerobic digestion in one year. Also adding bacterial cultures and inorganic that can promote anaerobic digestion.
Other comments	

KPI_SI_3 calculation	Description	Responsible
STEP 1	Measure the volume of biogas produced specifically from mechanically processed biomass and added anaerobic cultures, focusing on enhancing the biogas yield. Measurement: Volume of biogas in m³/day from processed biomass.	KIS
STEP 2	Quantify the volume of biomethane produced from the biogas and determine the conversion efficiency from biogas to biomethane. Measurement: Volume of biomethane in m³/day and conversion rate as a percentage.	KIS
STEP 3	Calculate the KPI by considering the efficiency and effectiveness of the conversion process from biogas to biomethane, reflecting the project's success in optimizing bioenergy production. Formula: Biomethane efficiency = (Volume of biomethane input / Volume of biogas from processed biomass) * 100%.	KIS

KPI ID	KPI_SI_4
KPI Name	Biomass conversion efficiency in biochar production
Strategic Objective(s)	O2: To optimise agricultural/forest waste management reducing the associated emissions O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC SI.04: Biochar maximum utilization
Responsible	BIOMASA, IRI UL
KPI Description	This KPI will monitor the Biomass input consumption in biochar production process. This KPI will indicate the production curve for several operational temperature setpoint and biomass burning duration in order to identify direction of production improvement and optimal production operational parameters.
KPI Formula	$$P_E = \frac{M_{Biomass(kg,t)}}{M_{Biochar(kg,t)}}$$

Variables explanation	Masses of the consumed biomass fuel and of produced biochar will define the efficiency of biochar production process.
Unit of measurement	Kilograms, tonnes of biomass inputs and biochar product
Baseline	The efficiency of business as usual of the operation will serve as a baseline value for comparison. The usual efficiency ratios of operation can reach up to 90-95%. The initial runs of the CHP plants will define baseline efficiency value which will be investigated through several temperature setpoints in the demo.
Target / Thresholds	The overall system efficiency should remain on level, which still yields profitable operation with consideration with additional revenues from flexible operation and the biochar production.
Other comments	Several temperature setpoints of operation will be evaluated in this UC.

KPI_SI_4 calculation	Description	Responsible
STEP 1	Amount of biomass fuel, used in one cycle.	BIOMASA
STEP 2	Amount of biochar product in one production cycle.	BIOMASA
STEP 3	Comparison of biochar production for several temperature setpoint.	UL

KPI ID	KPI_SI_5
KPI Name	Biomass conversion efficiency in power and heat generation
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1: Innovative and efficient biogas production and conversion process KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
Related Use Case	UC SI.03: Modular design of biomass slow pyrolysis system solution
Responsible	BIOMASA, IRI UL
KPI Description	This KPI will monitor the efficiency of the designed modular CHP system.

KPI Formula	$$E_T = \frac{W_T}{M_{Biomass}}, E_E = \frac{W_E}{M_{Biomass}}$$
Variables explanation	Masses of the consumed biomass fuel and of produced thermal and electric energy define the efficiency of modular CHP system.
Unit of measurement	Kilowatt hours of produced thermal and electric energy over a mass of consumed biomass fuel in kg or tonnes.
Baseline	The efficiency of large-scale CHP systems (located in Biomasa centre) will define the baseline efficiency ratio, which will evaluate the performance of small, modular unit.
Target / Thresholds	The target for small, modular units' performance ratio is the profitability of the operation, as the potential buyers are looking for efficient and more economically optimized source of electric and thermal energy.
Other comments	

KPI_SI_5 calculation	Description	Responsible
STEP 1	Monitoring of the fuel amount: kg/tonnes of biomass, used for CHP operation.	BIOMASA
STEP 2	Monitoring of electric and thermal generation to determine the yields of operation.	BIOMASA
STEP 3	Calculation of efficiency levels per day, different biomass used and other parameters, which will be varied during pilot operation.	IRI UL

KPI ID	KPI_SI_6
KPI Name	Bid success rate
Strategic Objective(s)	O1: To promote the penetration of decentralized renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process

Related Use Case	UC SI.02: Utilization of flexibility of the biomass centre Nazarje
Responsible	SETUP, BIOMASA
KPI Description	The bid success rate measures the percentage of market bids successfully accepted. This KPI indirectly measures the aggregator's capability to evaluate market conditions and strategically place optimal bids for both power quantity and price.
KPI Formula	$$BSR = \frac{N_{Bids\_ok}}{N_{total}} \times 100\%$$
Variables explanation	BSR [%]: Bid success rate N_{Bids_ok}: The number of accepted market bids from the system operator N_{total}: The total number of market bids placed
Unit of measurement	Percentage in %
Baseline	BIOMASA's flexibility assets do not participate in the ancillary services market. Therefore, the baseline cannot be defined.
Target / Thresholds	80%
Other comments	/

KPI_SI_6 calculation	Description	Responsible
STEP 1	The aggregator defines the observation period and calculates the number of bids sent to the market.	SETUP, BIOMASA
STEP 2	The aggregator inspects how many bids were not successful or invalid.	SETUP, BIOMASA
STEP 3	The aggregator calculates the KPI.	SETUP, BIOMASA

KPI ID	KPI_SI_7
KPI Name	Activation success rate
Strategic Objective(s)	O1: To promote the penetration of decentralized renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand

Related ECOLOOP innovation	KER 1.1: Flexibility management to increase the profitability of slow pyrolysis process
Related Use Case	UC SI.02 Utilization of flexibility of the biomass centre Nazarje
Responsible	SETUP, BIOMASA
KPI Description	The activation success rate measures the percentage of successful activations following the acceptance of the energy bid and the transmission of the activation signal by the system operator. After receiving the activation signal, the aggregator must initiate the requested power within a timeframe of less than 12.5 minutes. This timeframe is defined within the mFRR product, as the assets are envisioned to participate in the ancillary services market offering mFRR. If other products, for example, aFRR will be relevant, the timeframe for KPI will be adapted accordingly.
KPI Formula	$$\text{ASR} = \frac{N_{Activations\_ok}}{N_{total}} \times 100\%$$
Variables explanation	ASR [%]: Activation success rate $N_{Activations\_ok}$: The count of successful activations (the requested power was activated in less than 12.5 minutes) N_{total}: The total count of received activations from the system operator
Unit of measurement	Percentage in %
Baseline	BIOMASA's flexibility assets do not participate in the ancillary services market. Therefore, the baseline cannot be defined.
Target / Thresholds	95%
Other comments	/

KPI_SI_7 calculation	Description	Responsible
STEP 1	The aggregator defines the observation period and calculates the number of activation signals from the system operator.	SETUP, BIOMASA
STEP 2	The aggregator inspects how many activations were not successful.	SETUP, BIOMASA
STEP 3	The aggregator calculates the KPI.	SETUP, BIOMASA

KPI ID	KPI_SI_8
KPI Name	Set-point success rate
Strategic Objective(s)	O1: To promote the penetration of decentralized renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 1.1: Flexibility management to increase the profitability of the slow pyrolysis process
	KER 2: Optimal combination of different renewable energy technologies to address the needs of agricultural or forest processes
Related Use Case	UC SI.01 Optimize the operation and improve the security of supply of biomass centre Nazarje
	UC SI.02 Utilization of flexibility of the biomass centre Nazarje
Responsible	SETUP, BIOMASA
KPI Description	The set-point success rate measures the percentage of successful set-point settings after the activation signal from the system operator is received or the algorithm for technical and economic optimization sends the new set points and schedules. The new power must fall within ±5% of the defined set point.
KPI Formula	$$\text{SSR} = \frac{N_{Set-point\_ok}}{N_{total}} \times 100\%$$
Variables explanation	SSR [%]: Set-point Success rate
	$N_{Set-point\_ok}$: The count of successful set-point settings (the new power must fall within ±5% of the defined set point)
	N_{total}: The total count of sent set-points in the observed interval
Unit of measurement	Percentage in %
Baseline	Management of BIOMASA's flexibility assets is not performed. Therefore, baseline cannot be defined.
Target / Thresholds	80%
Other comments	/

KPI_SI_8 calculation	Description	Responsible
STEP 1	The aggregator defines the observation period and calculates the number of set points sent.	SETUP, BIOMASA
STEP 2	The aggregator inspects how many times set points were correctly set.	SETUP, BIOMASA
STEP 3	The aggregator calculates the KPI.	SETUP, BIOMASA

KPI ID	KPI_EE_1
KPI Name	Wood production of forest plantations in Estonian conditions
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
Related Use Case	UC EE.02: Carbon calculator for forest plantations UC EE.04: The potential wood production of different deciduous tree species on different soil types
Responsible	EULS
KPI Description	Potentially increased production (wood volume) of forest plantations with different tree species in comparison with the production of the same species on forestland. The production gain of wood volume in plantations is calculated as the percentage increase in comparison with natural forest.
KPI Formula	$\Delta Vol\ (\%) = \frac{VolPL - VolF}{VolF} x\ 100$
Variables explanation	ΔVol: relative difference in tree species wood volume (%) VolPL: wood volume in plantation (m3 ha-1) WVc: wood volume of the same tree species in natural forest (m3 ha-1)
Unit of measurement	Percentage (%)
Baseline	Productivity of the same species in natural forests.
Target / Thresholds	The desired increase should be around 5-15%.

Other comments	/

KPI_EE_1 calculation	Description	Responsible
STEP 1	Data collection in plantations of birch, aspen and alder.	EULS
STEP 2	Growth and yield modelling and calculation of difference between forest and plantation.	EULS
STEP 3	Improved yield models for different tree species plantations and their integration to carbon calculator.	EULS

KPI ID	KPI_EE_2
KPI Name	Biostimulant CO2 gain at the ecosystem level in forest plantations
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand O3. To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols (WP4)
Related Use Case	UC EE.03: New environmentally friendly biostimulants and fertilizers to enhance the production of forest plantations UC EE.02: Carbon calculator for forest plantations
Responsible	EULS
KPI Description	Potentially increased ecosystem CO2 sequestration rate of forest plantations after novel biostimulant (arGrow, AB, Sweden) treatment in comparison with the untreated ecosystem (control). The ecosystem CO2 contains aboveground biomass and soil. The CO2 gain is calculated as the percentage increase in comparison with the control area.
KPI Formula	$CO2G = \frac{(CO2b - CO2c)}{CO2c} \times 100\%$
Variables explanation	CO2G: ecosystem CO2 gain (%)

	CO2b: ecosystem CO2 stock with biostimulant (Mg CO2 equivalent ha-1)
	CO2c: ecosystem CO2 stock without biostimulant (Mg CO2 equivalent ha-1)
Unit of measurement	Percentage (%)
Baseline	Ecosystem CO2 stock without biostimulant treatment.
Target / Thresholds	The desired increase in the percentage of CO2 sequestration should be around 20%.
Other comments	

KPI_EE_2 calculation	Description	Responsible
STEP 1	Data collection: defining the baseline of ecosystem CO2 stocks in forest plantations without biostimulant.	EULS
STEP 2	Data collection: defining the ecosystem CO2 stocks in forest plantations with biostimulant.	EULS
STEP 3	Ecosystem CO2 stocks modelling and gain (%) calculation.	EULS
STEP 4	Improved ecosystem CO2 stock models with biostimulant and their integration to carbon calculator.	EULS

KPI ID	KPI_EE_3
KPI Name	Biostimulant growth and yield gain in forest plantations
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols (WP4)

Related Use Case	UC EE.03: New environmentally friendly biostimulants and fertilizers to enhance the production of forest plantations
	UC EE.02: Carbon calculator for forest plantations
	UC EE.04: The potential wood production of different deciduous tree species on different soil types
Responsible	EULS
KPI Description	Potentially increased yield (wood volume) of forest plantations after novel biostimulant (arGrow, AB, Sweden) treatment in comparison with the untreated trees (control). The yield gain of wood volume is calculated as the percentage increase in comparison with the control area.
KPI Formula	$YG = \dfrac{(WVb - WVc)}{WVc} * 100\%$
Variables explanation	YG: yield gain (%)
	WVb: wood volume with biostimulant (m3 ha-1)
	WVc: wood volume without biostimulant (control) (m3 ha-1)
Unit of measurement	Percentage (%)
Baseline	The wood volume without biostimulant treatment.
Target / Thresholds	The desired increase in the percentage of wood volume yield should be around 20%.
Other comments	

KPI_EE_3 calculation	Description	Responsible
STEP 1	Data collection: defining the baseline of wood volume yield in forest plantations without biostimulant.	EULS
STEP 2	Data collection: defining the wood volume yield in forest plantations with biostimulant.	EULS
STEP 3	Growth and yield modelling and gain (%) calculation.	EULS
STEP 4	Improved yield models with biostimulant and their integration to carbon calculator.	EULS

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KPI ID	KPI_EE_4
KPI Name	Biorefinery´s feedstock properties of woody biomass in forest plantations
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
Related ECOLOOP innovation	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols (WP4)
Related Use Case	UC EE.02: Carbon calculator for forest plantations
	UC EE.04: The potential wood production of different deciduous tree species on different soil types
Responsible	FIBENOL
KPI Description	Testing the feedstock properties of deciduous tree species to meet the quality requirements (heavy metals and macro chemical properties) for wood in forest plantations. Forest plantations are growing on former agricultural lands, which have been fertilized intensively during their past agricultural use. Agricultural fertilizers heavy metal residuals in soil might be accumulated to tree biomass and reduce the feedstock quality for some products. Forest plantations wood quality may be lower than in forest land, and therefore, their chemical composition might be lower. Feedstock quality determines the CO_2 displacement factor in carbon calculator. Forest plantations feedstock quality is compared with forest land wood quality.
KPI Formula	$FQi = \frac{(FPp - FPf)}{FPf} * 100\%$
Variables explanation	FQ: Feedstock quality change for property i (%)
	FPp: any feedstock property, such as cost, CO_2 footprint, mechanical properties, or chemical composition (e.g. heavy metal or chemical concentration in biomass) in forest plantation
	FPf: any feedstock property, such as cost, CO_2 footprint, mechanical properties, or chemical composition (e.g. heavy metal or chemical concentration in biomass) in forest land
Unit of measurement	Percentage (%)
Baseline	Feedstock properties in forest land (uncontaminated sites from fertilizers).
Target / Thresholds	0% or higher (no deterioration in quality)
Other comments	

KPI_EE_4 calculation	Description	Responsible
STEP 1	Data collection: wood samples from the experimental sites.	EULS
STEP 2	Evaluation of properties, including lab analyses: heavy metals and chemical properties.	EULS
STEP 3	Quality assessment of plantations wood and their displacement factors in fossil substitution (avoided CO_2 emissions).	FIBENOL
STEP 4	Integration of substitution factors to carbon calculator for climate benefit estimation of novel bioproducts.	FIBENOL

KPI ID	KPI_EE_5
KPI Name	User evaluation of the Carbon Calculator
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
	O2: To optimise agricultural/forest waste management reducing the associated emissions
	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
	O4: To foster regional development in rural areas while empowering farmers' and foresters' by means of innovative BMs, financial instruments and policy recommendations
Related ECOLOOP innovation	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols
	KER 6: Economic and social support for farmers' and foresters' engagement as prosumers of renewable energy
Related Use Case	UC EE.02: Carbon calculator for forest plantations
Responsible	EULS
KPI Description	Carbon calculator will be developed as a working on-line tool. A group of test users (random selection of potential users) will be asked to rate the user-friendliness, understandability and informativeness of the tool on a 10-point scale.

KPI Formula	Grade=∑gradein $Grade = \sum gradein$
Variables explanation	Grade: average grade Gradein: grade given by individual test user N: number of test users
Unit of measurement	Grade from 1 (most negative experience) to 10 (most positive experience).
Baseline	Does not apply
Target / Thresholds	The desired grade should be above 7.
Other comments	

KPI_EE_5 calculation	Description	Responsible
STEP 1	Selection of test users within groups of interest (e.g. landowners, policy makers).	EULS
STEP 2	Test users are provided access to Carbon Calculator and asked to rate it based on their experience.	EULS
STEP 3	Average user rating given for different aspects of the Carbon Calculator will be assessed to make potential improvements and revisions to the tool.	EULS

KPI ID	KPI_EE_6
KPI Name	Nutrient-rich wood ash CO_2 gain at the ecosystem level in forest plantations on organic soils
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater

	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols (WP4)
Related Use Case	UC EE.01: Wood ash recycling system for forest plantations UC EE.02: Carbon calculator for forest plantations
Responsible	EULS
KPI Description	Potentially increased ecosystem CO2 sequestration rate of forest plantations on organic soils after macro- and micronutrients rich wood ash treatment in comparison with the untreated ecosystem (control). The ecosystem CO2 contains aboveground biomass and organic soil. The CO2 gain is calculated as the percentage increase in comparison with the control area.
KPI Formula	$CO2G = \frac{(CO2b - CO2c)}{CO2c} * 100\%$
Variables explanation	CO2G: ecosystem CO2 gain (%) CO2b: ecosystem CO2 stock treated with wood ash (Mg CO2 equivalent ha-1) CO2c: ecosystem CO2 stock without wood ash (Mg CO2 equivalent ha-1)
Unit of measurement	Percentage (%)
Baseline	Ecosystem CO2 stock without wood ash treatment.
Target / Thresholds	The desired increase in the percentage of CO2 sequestration on organic soil should be around 20%.
Other comments	

KPI_EE_6 calculation	Description	Responsible
STEP 1	Data collection: defining the baseline of ecosystem CO2 stocks in forest plantations on organic soils without wood ash.	EULS
STEP 2	Data collection: defining the ecosystem CO2 stocks in forest plantations with wood ash treating on organic soils.	EULS
STEP 3	Ecosystem CO2 stocks modelling and gain (%) calculation.	EULS
STEP 4	Improved ecosystem CO2 stock models with wood ash and their integration to carbon calculator.	EULS

KPI ID	KPI_EE_7
KPI Name	Nutrient-rich wood ash effect on the production in forest plantations growing on organic soils
Strategic Objective(s)	O1: To promote the penetration of decentralised renewable sources in the energy system of agriculture and forestry sectors and improve cost-effectiveness, sustainability and circularity of agriculture and forest sectors energy demand
	O3: To enhance soil properties biodiversity and health and groundwater conditions by means of advanced bioproducts
Related ECOLOOP innovation	KER 3: Bioproducts to create positive effects in soil health, biodiversity and groundwater
	KER 5: Carbon sequestration tool calculation and renewable-based agricultural protocols (WP4)
Related Use Case	UC EE.01: Wood ash recycling system for forest plantations
	UC EE.02: Carbon calculator for forest plantations
	UC EE.04: The potential wood production of different deciduous tree species on different soil types
Responsible	EULS
KPI Description	Potentially increased yield (wood volume) of forest plantations on organic soils after macro- and micronutrients rich wood ash treatment in comparison with the untreated trees (control). The yield gain of wood volume is calculated as the percentage increase in comparison with the control area.
KPI Formula	$YG=\frac{(WVb-WVc)}{WVc}*100\%$
Variables explanation	YG: yield gain (%)
	WVb: wood volume with wood ash (m3 ha-1)
	WVc: wood volume without wood ash (control) (m3 ha-1)
Unit of measurement	Percentage (%)
Baseline	The production of unfertilized control area plantations on organic soils.
Target / Thresholds	The desired increase in the percentage of wood volume yield on organic soils should be around 20%.
Other comments	

KPI_EE_7 calculation	Description	Responsible
STEP 1	Data collection: defining the baseline of wood volume yield in forest plantations on organic soils without wood ash treating.	EULS
STEP 2	Data collection: defining the wood volume yield in forest plantations treated with wood ash.	EULS
STEP 3	Growth and yield modelling and gain (%) calculation.	EULS
STEP 4	Improved yield models with wood ash and their integration to carbon calculator.	EULS