GREENChainSAW4Life

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"GREEN energy and smart forest supply CHAIN as drivers for a mountain action plan towards climate change"

Deliverable number DL.C7.2

Standard procedures for the efficient provision of wood biomass and Assessment of the chipped wood quality and performance of the biomass in the different plants

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ABSTRACT

This comprehensive overview explores the integration of Green Plasma technology within the biomass-to-energy conversion sector, with a particular focus on forest waste treatment as part of the GREENChainSAW4Life project. The document outlines the various stages of the process, including the importance of logistics for transporting biomass from collection sites to treatment. It starts with the evaluation of the quality of biomass and wood chips, crucial to ensuring efficient and continuous supply flow. Through careful analysis of characteristics such as moisture content, particle size, and ash content, compatibility with the Green Plasma system is ensured.

Subsequently, the impact of biomass quality on the operational efficiency of Green Plasma technology is examined in the context of logistics, highlighting the importance of optimized material flow management to maximize overall process efficiency. Specific strategies are then proposed to improve the quality of wood chips and optimize the biomass treatment process, considering logistical aspects such as transportation management and material storage.

Finally, the final performance analysis considers not only technical and economic aspects but also the impact of logistics on the overall efficiency of the system. This approach ensures a comprehensive evaluation of the role of Green Plasma technology in sustainable forest waste management and energy production, with particular attention to its integration into logistical processes.

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1. INTRODUCTION

1.1 CONTEXTUALIZATION WITHIN THE GREENCHAINSAW4LIFE PROJECT

OVERVIEW OF GREEN PLASMA TECHNOLOGY AND ITS RELEVANCE TO BIOMASS TREATMENT

The Green Plasma technology represents a pioneering approach in the field of biomass treatment, specifically tailored to address the challenges associated with converting residual forest biomass into energy. This innovative technology exposes the material such as biomass to high temperatures of 900°C, capable of initiating various chemical reactions. The main advantage of Green Plasma technology lies in its ability to efficiently break down complex organic materials into simpler and energy-rich gases, primarily syngas (synthesis gas), which is a mixture of hydrogen, carbon monoxide, and minimal amounts of carbon dioxide. The significance of Green Plasma technology for biomass treatment stems from its versatility and environmental sustainability. Unlike conventional combustion processes, plasma gasification operates at significantly higher temperatures, ensuring a more complete breakdown of organic materials, including lignocellulosic biomass present in forest residues. This results in a reduction in the production of unwanted by-products such as tar and ash, which are common challenges in traditional biomass gasification processes. Additionally, Green Plasma technology has the capability to process a wide range of biomass feedstocks, including those with high moisture content or irregular sizes, which are often deemed unsuitable for conventional treatment methods.

By converting forest residues, which would otherwise contribute to carbon emissions through decomposition or incineration, into a clean and renewable energy source, Green Plasma technology plays a crucial role in the circular economy and sustainable forest management. As part of the GREENChainSAW4Life. project, green plasma technology is instrumental in demonstrating the possible way to utilise forest and other residual biomass. The project aims to show an efficient, scalable and environmentally friendly solution for energy production. This not only meets the immediate needs of energy production, but also contributes to broader objectives such as reducing dependence on fossil fuels, mitigating climate change and promoting sustainable forestry practices.

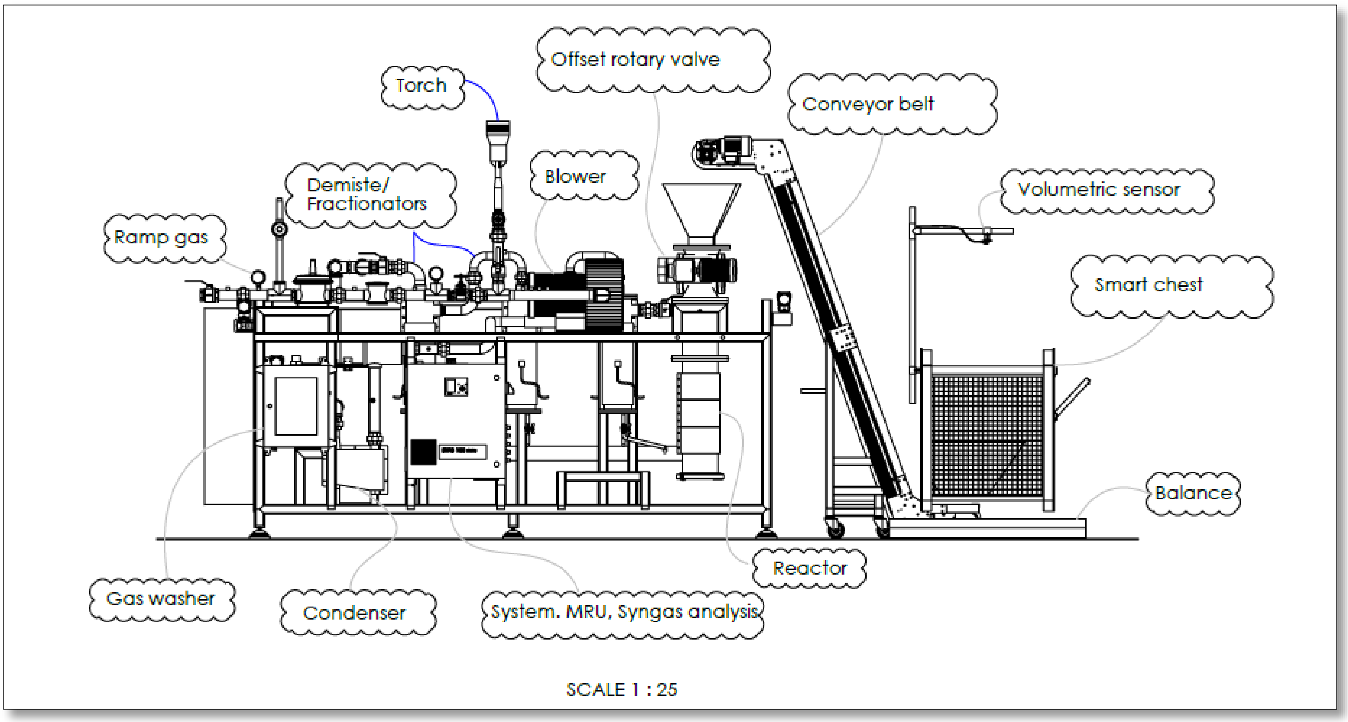


Figure 1.1

1.2 OBJECTIVES OF DL.C7.2 IN ANTICIPATION OF THE FINAL PERFORMANCE ANALYSIS IN DL.C7.3

The deliverable DL.C7.2, focusing on "Standard Procedures for the Efficient Supply of Woody Biomass and the Evaluation of Wood Chip Quality and Biomass Performance in Different Plants," lays the foundations for a complete understanding and evaluation of Green Plasma technology within the GREENChainSAW4Life project. The primary objectives of DL.C7.2, as they align and lead to the final performance analysis in DL.C7.3, include several key areas:

Definition of reference data: Before any performance analysis can be performed, it is essential to establish a solid data base for the current processes involved in the collection, processing and conversion of biomass.

Optimization of biomass supply and processing processes: One of the critical objectives of DL.C7.2 is to optimize the logistical and operational aspects of biomass supply, including collection, chipping and transport. By developing and documenting standard procedures, DL.C7.2 will ensure that the biomass fed into the Green Plasma technology is of consistent quality and is provided in an efficient and sustainable manner, essential for subsequent performance analysis.

Quality Assessment of Treated Biomass: A significant portion of DL.C7.2 is dedicated to assessing the quality of biomass post-treatment, focusing on parameters such as particle size, moisture content, and energy potential. These assessments are vital for understanding how well the Green Plasma technology performs in transforming raw forest residues into a high-quality, energy-dense feedstock, setting the stage for a detailed performance analysis in DL.C7.3.

Evaluation of the quality of treated biomass: a significant part of DL.C7.2 is devoted to the evaluation of the quality of post-treatment biomass, focusing on parameters such as particle size, moisture content and energy potential. These assessments are crucial to understand how well Green Plasma technology behaves in transforming raw forest residues into a high quality raw material. By establishing standard procedures and quality parameters in DL.C7.2, the project will be equipped to conduct a solid comparison that highlights the advantages and potential areas for the improvement of Green Plasma technology.

Identification of challenges and preliminary solutions: Through the activities and analyses conducted in DL.C7.2, the first challenges in the process of converting biomass into energy can be identified using Green Plasma technology.

Set the stage for the final performance analysis: Ultimately, the goal of DL.C7.2 is to set a complete and solid phase for DL.C7.3, where the final performance analysis of Green Plasma technology will take place, with the evaluation of the quality of the product and all its logistical and non- and its traceability.

1.3 COMPARISON OF GREEN PLASMA WITH TRADITIONAL BIOMASS TREATMENT METHODS

In the comparison between Green Plasma technology and conventional combustion or gasification paradigms, our Green Plasma technology offers distinct advantages in terms of efficiency and sustainability. Eliminates combustion in the conversion process from biomass to syngas, reducing harmful emissions and environmental pollutants. The use of electricity for heating adds a circular and sustainable element to the system, reducing dependence on fossil fuels and integrating renewable energy sources. In addition, it produces syngas with a high calorific value of 4.5 MJ/m3. During our tests we highlighted the importance of calcium oxide (Cao) as a gas treatment method, which we have seen that further improves the quality of the gases. The reprocessing of condensed liquids minimizes solid or liquid residues and simplifies the management of by-products, minimizing environmental impact. Compared to conventional combustion, with Green Plasma and high temperature pyritization we produce cleaner synthesis gases with higher concentrations of hydrogen (H_2) >20% and carbon monoxide (CO) >15% (CH_4) 10% and lower harmful emissions. The innovative approach of Green Plasma technology optimizes the gasification phases, leading to greater efficiency and gas quality. The ash produced during the process undergoes a chemical transformation reduced to a minimum, simplifying the treatment and promoting the recycling of materials.

After numerous tests, we found that Green Plasma technology offers greater energy efficiency, reduced environmental impact and long-term sustainability.

Figure 1.2. data taken with Green plasma system SWG100 MRU test.

	Green Plasma System	Traditional pyro gasification
Plant feed	High temperature, over 900°C	Lower temperature, around 600°C
Energy source	Electric power, derived from the syngas and green energies	Powered by fossil fuels
Plant efficiency	Energy efficiency controlled by PLC and integrated system, industry 4.0	Traditional system.
Emissions	Not harmful emissions. Absence of combustion, minimal Dioxide fractions	Traditional combustion with higher fractions of Dioxide.
Syngas cleaning	Gas treatment, chemical reagents (CaO), scrubber	Not a gas treatment
Final solid residue	Solid wasted reduction by process at higher temperature. Less biochar.	Significant solid residues
Final gas type	Higher quality of gas, higher H2, and calorific power	Low gas quality

Figure 1.3. Comparison of Green Plasma technology with traditional biomass treatment methods.

1.4 TREATMENT OF HIGH-TEMPERATURE BIOMASS ASHES

High temperature biomass ash treatment is a key aspect of Green Plasma technology. During the conversion process from biomass to syngas, residual ash is produced as a by-product. However, thanks to the high temperatures reached thanks to the electrical resistances, these ashes undergo a transformation that makes them less in quantity, less than 3% of the initial wood chips susceptible to dispersion and reprocessing. The resulting ash is characterized by greater chemical stability and a decrease in its ability to release pollutants into the surrounding environment. In addition, the high temperature treatment process helps to reduce the amount of solid residues and makes the ash more suitable for reuse or safe disposal. Proper ash management maximizes the overall efficiency of the process and minimizes the overall environmental impact, with very few of which we can handle cleaning well during testing. Ash from high temperature treatments can be replenished in the plant for various purposes. One possibility is to use them as part of the material for the gasification process itself, thus contributing to more efficient resource management and waste reduction.

In addition, very important processed ash can be used as a building material or agricultural fertilizer, providing an opportunity for recycling and sustainable reuse of these by-products. This approach not only reduces the need for ash disposal, but can also lead to further benefits in terms of environmental sustainability and cost reduction.

1.5 TRACEABILITY AND SUPPLY CHAIN MANAGEMENT SYSTEM

The following logistic diagram illustrates how the management of the logistics and traceability process for the material was conducted.

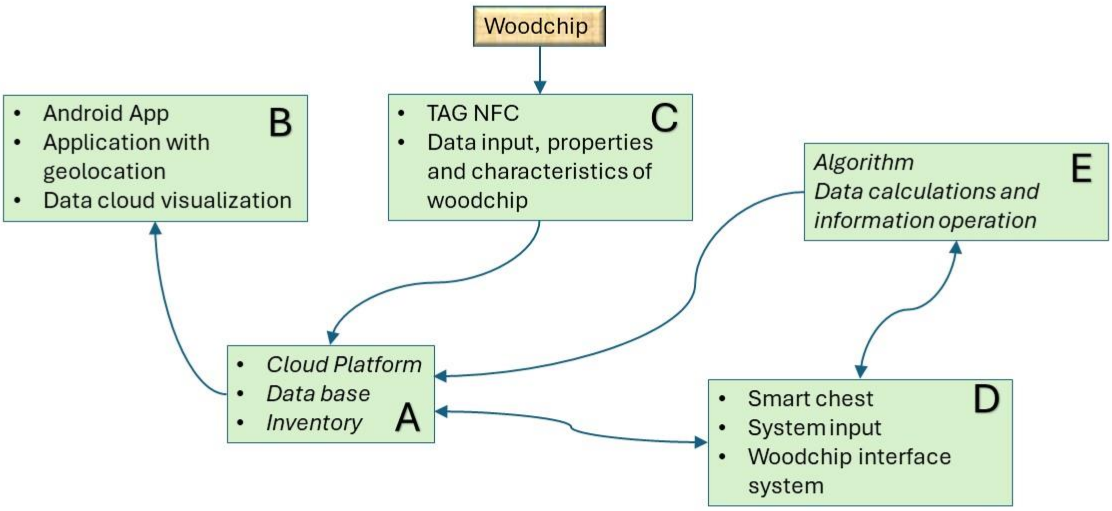


Figure 1.4. Logistic diagram process

A: **The Cloud platform** serves as a central point for collecting and storing all data from devices and applications used in the biomass supply chain management.

B: **The Android application with geolocation** allows operators to collect on-site data and visualize such as the location of biomass collection and transportation devices and upload them directly to the Cloud platform.

C: **NFC tags** are used to store and transfer specific information about various points in the supply chain. These tags can be read and written through the Android application, enabling direct transfer of data to the Cloud platform.

D: **The smart chest** is equipped with humidity and weight sensors that monitor the conditions of the biomass material during transportation. The collected data is transmitted through the NFC tag and the Android application to the Cloud platform for processing and analysis.

E: **Algorithm**, calculations and manage of information, in this stage all the calculations are made in order to get a outline of information useful to trace the woodchip lifecycle.

Table 1.1. Phases forest woodchips management.

Phase	Goal in proposal	Technology developed in the project	Method
Phase 0: Forest management carried out through Decision Support System (DSS).	Cloud sharing of information from planning and management tools (quantity of wood harvested, assortment type, species, site location, etc.).	Cloud Platform (A) for collecting all data from: - Android application with geolocation (B) - NFC tags (C)	Upon the arrival of the wood chip transport vehicle, these operations will be carried out.
	Free access to information.	Use of an open Cloud platform with some data visible without credentials.	
	Introduction of a payment system for wood chips based on: - Monitored characteristics of the wood chips throughout the process - Overall energy yield - Impact on the efficiency of the plant operation	In the current phase, it is not yet planned.	
	Collection and digitization of data in a way that they are accessible through a virtual platform, viewable remotely, and processable to generate real-time documents such as transport records, invoices, and other necessary/useful documents for businesses along the supply chain and end customers.	Cloud platform for gathering all data and providing a summary report sheet.	
Phase 1: Forest or collection area.	Localization of the forest or collection area with coordinates and forest data.	Android application with geolocation (B).	
Phase 2: Material departure management	Automatic summary description of the starting material (quality, quantity);	(C) NFC tag capable of storing all data such as humidity, weight with the possibility of reading and writing from Android application (B) with the ability to transfer data directly to the cloud (A).	Once the chipping phase is completed, the wood chips will be collected in large bags. Each bag used for transporting the wood chips will be equipped with a perforated NFC tag so that it can be securely fastened using screws or similar methods.
Phase 3: Transportation	Insertion into the cloud of the entire chip supply chain from its origin to its utilization	Cloud platform (A) for collecting all data derived from NFC tags (C) through Android application (B)	Before the shipment is sent to the central headquarters, an operator using a specific Android application must load all the required information into the NFC tags.

	Creation of a data sharing platform integrating multiple storage systems aimed at sharing transportation systems and reducing overall emissions and associated costs. Establishment of organized short supply chains.	In the current phase, it is not yet planned.	
Phase 4: Material Management Upon Arrival	Automatic summary description of incoming material (quality, quantity).	Smart chest (D) in the arrival area: - Humidity sensor - Weight sensor	Upon the arrival of the containers at the central headquarters, the following operations will be carried out using an NFC reader connected to a computer: - Read the content - Verify the reliability of the data contained in the tags - Upload the read data to the cloud
Phase 5: mCHP Management	Defining the intensity of the drying process required in the dryer.	Smart chest (D)	Measurement of humidity at the beginning of treatment and at the entry into the gasifier
	Correlate starting moisture content of the wood chips, final moisture content, energy required for drying, energy produced, and overall energy efficiency considering extraordinary maintenance downtime.	Sensors will be placed between the dryer and the gasifier to monitor hourly wood chip consumption, overall energy efficiency, and estimate autonomy times.	Electricity meters will be integrated into the dryer's power supply system to monitor energy consumption. Additionally, an electricity meter will be installed to measure the electricity generated by the gasifier based on the previously recorded data on humidity and energy.
	Automate the ordering process for wood chips.	Computer platform capable of connecting and analyzing previous data and communicating with a logistics portal to place new orders.	When a minimum volume of wood chips is reached, an MQTT alert message is sent.

In the preceding table, the different stages of woodchip material management are outlined. *Table 1.1* presents these stages along with their respective objectives, developed technology, and the methods by which these stages are achieved. The *Figure 1.5.* provides a concise diagram summarizing the table explaining the various phases of woodchip material management.

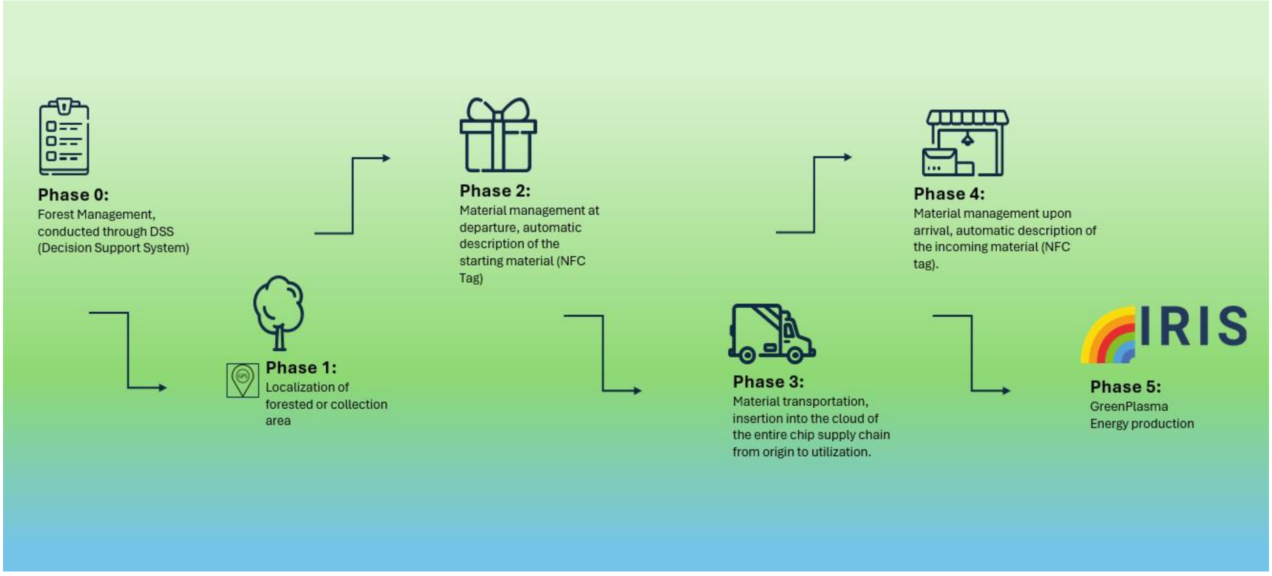


Figure 1.5. Phase diagram.

2. DESCRIPTION OF BIOMASS SOURCING FROM EXPERIMENTAL FOREST PLOTS

2.1 PRE-TREATMENT PROCESSES AND CRITERIA FOR SELECTING BIOMASS FOR GREEN PLASMA TECHNOLOGY

The effective use of Green Plasma technology for biomass conversion into energy necessitates a rigorous pre-treatment process and a careful selection of biomass based on specific criteria. These steps ensure that the biomass is in an optimal state for plasma gasification, maximizing efficiency and sustainability. This section delves into the pre-treatment processes and the essential criteria for biomass selection tailored for Green Plasma technology.

2.1.1. Size Reduction

Biomass is mechanically reduced to a uniform size by our tests is preferable to minus equal 5 cm, easy through chipping or shredding. Constant particle size helps achieve uniform gasification rate, improving overall process efficiency. For uniform and efficient gasification, biomass must be of consistent size.

Figure 2.1. Woodchips shredded and NOT shredded.

The preparation of woodchips as showed in *Figure 2.1* involves increasing their relative density, which leads to an increase in the surface area of the woodchips exposed to high temperatures within the reactor, thereby facilitating pyrolysis. Additionally, this pretreatment helps to reduce any excessive moisture content present in the woodchips. In

Figure 2.1 Woodchips shredded with density 241 g/l; instead before pre-treatment without shredded the woodchips with density 178 g/l.

Figure 2.2. Woodchip being shredded.

2.1.2. Screening and sorting

This step involves removing contaminants and non-organic materials such as stones, metals or foreign objects that may have been mixed with biomass. Screening can be both visual and control upstream in the supply chain with their selection technologies, this ensures the purity of biomass, preventing potential damage to gasification equipment and ensuring the quality of the syngas produced.

2.1.3. Homogenization

Biomass collected from various sources may have different characteristics. Homogenization mixes different types of biomass to obtain a consistent raw material with uniform chemical and physical properties. This process helps to stabilize the gasification process and predict the quality of the output syngas more reliably, so during the tests we shredded and mixed the wood chips to homogenize it.

Figure 2.3 Part of the wood chips scrap stored on site.

2.1.4. Criteria for Selecting Biomass:

The GreenChainSAW4Life project meticulously selects biomass based on strict criteria to optimize the efficiency and sustainability of Green Plasma technology. Factors such as energy content, moisture and ash levels, chemical composition and physical properties are carefully evaluated. Unlike traditional methods, the high moisture content in the wood chips is not a problem but a resource for the purposes of the process, during the tests we saw an improvement of the H2 when there was a natural moisture of the wood chips without drying. While careful evaluation of the waste end processing ash is minimal. Physical properties such as bulk density, chip size and shape are considered relevant for the purposes of the process.

2.2 LOGISTICAL PROCESS, PROCEDURES

In addition to the characteristics and processes of preparation of wood chips such as drying, sizing and selection, an integral aspect of their collection and transport is the traceability of materials. After collection from the woods, the wood chips are placed individually in designated containers, especially big bags, and marked with NFC technology. This marking process assigns essential information on the geolocation of wood chips and key characteristics.

Figure 2.4. Woodchip in big bags

Biomass transport logistics prepared for treatment plants is strategically organised to minimise carbon footprint and transport costs. Using the Forest Information System, the project orchestrates the movement of biomass in a way that reduces travel distances and optimizes load capacities. Particular attention is paid to the planning of harvests and deliveries in line with the operational capabilities of treatment plants, ensuring a constant and manageable flow of raw materials from biomass. The logistical arrangements for the transport of biomass to the treatment sites of Green Plasma technology in the project GREENChainSAW4Life focus on route optimization, vehicle selection, coordination with treatment plant programs, sustainable transport practices, cloud-based logistics management and continuous improvement. Utilize advanced logistics software and GIS to minimize travel distance, reducing fuel consumption and emissions.

2.2.1. Vehicle Selection and Load Maximization

Choose vehicles based on load capacity, fuel efficiency, and terrain suitability. Maximize load capacity to reduce trips. Utilize GPS and real-time tracking for route adjustments.

2.2.2. Coordination with structure schedules

Synchronise biomass transport with treatment plant schedules to ensure a constant flow of raw materials and prevent bottlenecks.

2.2.3. Cloud-Based Logistics Management

Use a Cloud platform (A) for transparent management of wood chip transportation data. NFC Tags (C) and an Android (B) application enable real-time tracking and data recording, fostering collaboration and reducing transportation times and costs.

2.2.4. Continuous Improvement and Adaptation

Gather feedback from stakeholders for ongoing evaluation and improvement, remaining adaptable to implement new technologies and methodologies for optimizing the biomass transport process.

This expanded logistical approach addresses key aspects of the process, including storage of woodchips in big bags, woodchip information stored in an NFC tag, NFC tag read upon arrival at the facilities, cross-referencing with data from the smart cabin, aggregation of physical properties of the woodchip and database operations, determination of inventory status and material request via PLC algorithm, calculation of energy produced by the material, transmission and storage of data on the Cloud platform, visualization of information through an Android application, geolocation of the material's origin on the application, and closure of the material traceability cycle. To visualize the logistical approach and the keys aspect of the process. *Figure 2.5* show a diagram of the logical route of the process.

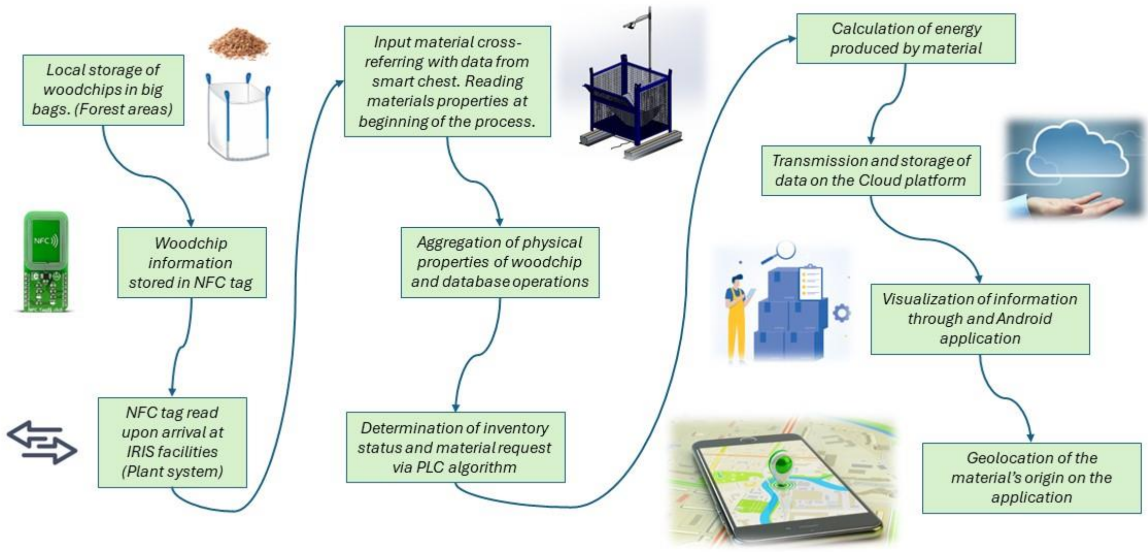


Figure 2.5. Diagram of logistic process

2.3 GREEN PLASMA TECHNOLOGY FOR BIOMASS TREATMENT

The initial phase of our company analysis consists in identifying and comparing the sensors available on the market to control the weight of the material and the type that enters the Pirogasification process. This critical step ensures the selection of the most reliable and accurate sensors capable of accurately monitoring moisture levels and the weight of raw biomass, thus optimizing the efficiency and performance of the Pirogasification system.

2.3.1. Humidity sensors:

Our Pirogasification system operates optimally within a specific range of moisture content for the fuel but is nevertheless operational at any humidity level. The use of humidity sensors allows real-time monitoring and facilitates corrective actions to maintain moisture levels within the desired range.

From our bibliographic and market analyses emerge different methodologies to measure the moisture content of incoming biomass. These methodologies are classified according to the type of quantity measured in absolute humidity (AH) and relative humidity (RH) sensors. Electrically, they are categorized as follows:

2.3.2. Capacitive sensors:

Operation: Capacitive sensors, primarily designed to measure relative humidity (RH), are essential where cost, size, and robustness are critical factors. They operate based on the variation of electrical permittivity of a dielectric material with humidity changes. Constructed with a capacitor and appropriate dielectric material, these sensors offer numerous advantages, including nearly linear output voltage, high stability, wide range of relative humidity measurements, and cost-effectiveness. They find applications in various sectors such as heating and air conditioning systems, printers, weather stations, automotive, food industry, freezers, ovens, and dryers.

Figure 2.6. Humidity sensors

2.3.3. Resistive sensors:

These sensors measure resistance or electrical conductivity in non-metallic conductive materials, which changes with humidity levels. Resistive humidity sensors offer advantages like lower cost, compact size, and easy interchangeability.

However, they are sensitive to chemical vapors and contaminants. Despite this drawback, they are widely used in various applications.

2.3.4. Near-Infrared (NIR) Technology:

NIR technology was deemed too costly for our needs, despite its accuracy. Capacitive sensors suit high temperatures, but for our purposes, the cost-effective and compatible resistive sensors are preferred. Specifically, resistive humidity sensors are chosen for their affordability, compact size, and ease of use, requiring no sample preparation.

2.3.5. Weight Measurement

Weighing incoming biomass, along with moisture measurement, is fundamental to ensure correct material flow as per the CBM commands. Multiple scales are available on the market. We will use this smart chest, which will provide the weight of the material along with many other data points.

Figure 2.7. Weight measurement

Figure 2.8. Integrated system for input control. Smart chest (D)

Conclusion: As part of the design of traceability sensors, we chose the most suitable sensor models and designed data acquisition and sharing systems for all stakeholders in the project. Our Green Plasma technology represents an innovative approach to the treatment of biomass, converting forest residues into valuable energy resources through gasification with heating resistors. It achieves a higher conversion efficiency, processes different raw materials from biomass, significantly reduces emissions, minimizes waste and aligns with broader environmental and energy objectives by providing a sustainable path for energy production.

3. DETAILED OVERVIEW OF GREEN PLASMA TECHNOLOGY AND ITS APPLICATION IN FOREST WASTE TREATMENT

3.1 PRELIMINARY ASSESSMENTS OF TECHNOLOGY'S EFFECTIVENESS IN BIOMASS CONVERSION

The implementation of Green Plasma technology in the project involves conducting preliminary assessments to evaluate its effectiveness in converting forest biomass into usable energy. These assessments encompass several key aspects:

3.1.1. Evaluation of conversion efficiency

It is a matter of measuring the caloric value of the syngas produced compared to the original biomass to evaluate the efficiency of the technology in the extraction of energy. Although we can treat any type of wood chips in any condition, this selection allows us to identify a type of material more performant, from the tests we highlight the wood chips a little wetter ensures high levels of H2.

3.1.2. Analysis of the composition of synthetic gases

We use for the tests a gas chromatograph SWG100 Biogas produced by the company MRU, which allows to analyse the composition of the syngas, focusing on hydrogen, carbon monoxide, on carbon dioxide and methane concentrations to determine the quality of the fuel produced, also provides us with data on the lower calorific value (PCI), which includes all compositions on average from the perspective of the efficiency of the syngas, Comparison meter for us in tests to see the quality of gas. If we want a more in-depth analysis we also have a mobile chromatograph gas (GC) produced by the company SRA that provides even more details on the pollutants that should there be now.

3.1.3. Environmental impact assessments

Evaluations include the measurement of pollutant levels in gases emitted during the gasification process and the analysis of solid residues to assess their environmental impact and potential treatment through different filters such as activated carbon or calcium oxide; the part of pollutants easily detectable also thanks to the GC that also noise the levels of benzene (CH), ethylene (-Et), propane (C3H8) and butane (C4H10).

3.1.4. Operational and Maintenance Assessments

These assess the technology's resilience to varying biomass qualities, operational stability, and maintenance requirements to ensure its long-term practicality and reliability.

3.1.5. Stakeholder Feedback and Expert Reviews

Gathering feedback from stakeholders and experts provides valuable insights into the technology's applicability, potential challenges, and areas for improvement, ensuring alignment with industry standards and regulatory requirements.

3.2 INTEGRATION WITH SOFTWARE PLATFORMS SUPERVISED BY COMPOLAB

The transport of wood chips is a crucial phase in the biomass supply chain, especially with regard to emissions and logistics cost optimization. The Cloud (A) platform plays a key role in ensuring efficient and transparent management of all information relating to the transport of wood chips, from origin to final destination. Through the use of NFC tags (C) and the Android application (B), we collect and record in real time all the information related to shipments of wood chips in transit. Before sending the load to headquarters, operators can upload all the necessary information on the NFC tags, such as the origin of the wood chips, the amount transported, the type of processing performed and other relevant logistics management data. The data sharing platform further optimizes the logistics process, enabling collaboration and resource sharing between different storage and transport systems. This encourages the creation of organised short supply chains, reducing transport times, costs and overall emissions associated with wood chip handling activities.

The integration of Green Plasma technology with advanced software platforms, under the supervision of CompoLab, marks a significant step towards the optimization of biomass conversion processes within the GREENChainSAW4Life project. This collaboration aims to exploit the potential of digital technologies to improve efficiency, monitoring and control of the biomass treatment process, ensuring continuous operation and more homogeneous and better distributed production.

3.2.1. Real-time monitoring and data acquisition

Integration begins with the creation of a complete real-time monitoring system. Sensors strategically located inside the green plasma reactor and along the biomass processing chain transmit crucial data on temperature, pressure, syngas composition and also for the intelligent caisson volume levels, sent to software platforms. This continuous flow of data enables immediate evaluation of the gasification process, allowing quick adjustments of operating parameters to maintain optimal performance.

3.2.2. Process optimization through data analysis

The collected data serves as a rich resource for advanced data analysis, conducted within software platforms. Machine learning algorithms (1.5 point traceability (E) algorithms and data), and predictive models analyse trends and models in operational data, identifying correlations between process variables and conversion efficiency. This analysis facilitates the development of optimization strategies.

3.2.3. Integration of control systems

These control systems (such as humidity sensors, pressure switches, volume sensors, etc.) ensure that the green plasma reactor operates under ideal conditions, adapting in real time to changes in the characteristics of biomass raw materials transmits from tracking (NFC) or to external conditions. This automation not only improves efficiency, but also reduces the potential for human error in process management. During the tests we check these systems through the PLC that allows us to automize much of the process also adjusting with the starting data that we have received, in a preventive way.

3.2.4. Environmental and Performance Dashboard

CompLab oversees the creation of an intuitive environmental and performance dashboard, accessible to project stakeholders. This dashboard visualizes key performance indicators, environmental metrics, and operational statuses, providing a comprehensive overview of the biomass conversion process. The dashboard facilitates informed decision-making and allows for the transparent reporting of the environmental impact and efficiency of the Green Plasma technology.

3.2.5. Maintenance and Troubleshooting Support

The software platforms also play a vital role in predictive maintenance and troubleshooting. By analysing operational data, the system can predict potential failures or maintenance needs before they lead to significant downtime. This predictive approach, combined with a detailed troubleshooting guide derived from historical data and expert knowledge, ensures the longevity and reliability of the Green Plasma technology.

3.2.6. Collaboration and Knowledge Sharing

Finally, the integration with software platforms fosters a collaborative environment among researchers, engineers, and operational personnel. The platforms serve as a knowledge hub, where insights, best practices, and lessons learned are shared, promoting continuous improvement in the biomass conversion process. This collaborative approach, facilitated by digital technologies, accelerates innovation, and enhances the scalability of Green Plasma technology.

3.3 LOGISTICS AND SUPPLY CHAIN MANAGEMENT

The objective is to ensure a sustainable, efficient and affordable flow of biomass from forest areas to conversion plants, in line with environmental standards and project objectives.

3.3.1. Sustainable procurement and collection with partners

The first step in the logistics chain is the procurement and collection of sustainable biomass. This involves identifying forest residues that can be collected without damaging the forest ecosystem. The project uses sustainable forest practices and special harvesting machinery, ensuring that biomass harvesting contributes to forest health and biodiversity. In addition to forest harvesting, we give priority to local biomass, we also collected a lot of material from wood processing chains, such as the partner company "Giusiano Legnami SRL", which provided us with many processing waste, a by-product for them, but for us new energy.

Figure 3.1 Giusiano legnami SRL

3.3.2. Biomass aggregation and pre-treatment centres

Once collected, the biomass is transported to nearby aggregation centres where it is subjected to first processing. This pre-treatment includes sizing and, if necessary, temporary storage. These centres are strategically positioned to minimize the transport distance of biomass from the collection sites, thus reducing transport costs and emissions.

3.3.3. Optimisation of transport routes

The project takes into account factors such as road conditions, vehicle capacity, biomass volume and fuel efficiency to minimise travel distances and reduce the carbon footprint associated with transport. This is thanks to real-time tracking (Cloud and Android application, part 1.5). We also use routing algorithms and G.I.S. (Geographical Information System) technology to design efficient collection routes, minimizing travel distances and time

3.3.4. Coordination with facilities and driver training, load consolidation:

Effective communication and coordination between the centres allows us to plan deliveries according to the operational capacity of the treatment plants, to avoid bottlenecks and ensure efficient treatment of biomass without unnecessary delays or storage costs. In addition, careful and safe driving training improves fuel efficiency. Coordinate biomass collection programs in multiple sites to consolidate loads, ensuring that transport vehicles operate at full capacity, reduce travel.

3.3.5. Use of forest information systems

The project leverages forest information systems (FIS) to improve logistics and supply chain management. FIS provides valuable data on forest resources, biomass availability and optimal collection points, facilitating strategic planning and decision making. The integration of FIS with traceability and the Cloud part allows you to adapt collection and transport plans in real time according to changing conditions or biomass availability.

3.3.6. Continuous improvement and scalability

Logistics and supply chain management strategies are subject to continuous evaluation and improvement. Lessons learned from initial operations are used to refine logistics models, improve efficiency and reduce environmental impact. The scalability of the logistics framework is also considered, ensuring that the supply chain can adapt to increased demand for biomass or expansion of treatment plants.

4. OPTIMIZATION OF LOGISTICS FROM BIOMASS COLLECTION TO TREATMENT FACILITIES

4.1 ROLE OF FOREST INFORMATION SYSTEM IN STREAMLINING BIOMASS SUPPLY CHAIN

The Forest Information System (FIS) is critical to optimizing biomass supply chains, particularly in project, here is a summary of its key roles:

4.1.1. Real-time data integration and visibility:

The FIS integrates real-time data from multiple sources, providing a unified view of the biomass supply chain for informed decision-making and a timely response to change.

4.1.2. Forest resource management:

Monitor forest health and the availability of residues to identify sustainable collection areas, ensuring that biomass harvesting does not damage ecosystems.

4.1.3. Stakeholder collaboration and information sharing:

FIS promotes collaboration between stakeholders, improving coordination across the supply chain for simplified operations.

4.1.4. Compliance and sustainability reporting:

The Forest Information System (FIS) supports compliance with environmental regulations and sustainability reports by providing detailed data on biomass supply, transport efficiency and environmental impacts. Key technical considerations include route optimization, load consolidation, the adoption of sustainable transport modes, the use of fuel-efficient vehicles and driver training on environmentally friendly driving. These considerations can be integrated into a detailed logistics plan to optimize biomass transport, ensuring efficient and sustainable flow throughout the supply chain. For traceability in logistics, it is crucial to identify the loading units and batches, with common systems including barcodes, NFC e RFID.

4.1.5. Choice of technology to be used:

As for traceability in logistics, technologies such as RFID and NFC

- RFID: used for resource monitoring and inventory management, with active and passive tags offering variable reading intervals and frequencies.

- NFC: facilitates secure data transfer, with short-range communications enabling applications such as contactless payments.

The differences lie in the use, infrastructure and complexity of the applications, with RFID mainly for monitoring and NFC for data transfer. In this context, NFC was deemed suitable for its secure communication and peer-to-peer capabilities.

4.2 QUALITY ASSESSMENT OF WOOD BIOMASS AND CHIPPINGS

This evaluation involves the evaluation of various physical and chemical properties of biomass to determine its efficiency. The key parameters and methodologies involved in quality assessment are described below:

4.2.1. Moisture content

The moisture content of woody biomass significantly affects its calorific value and the efficiency of the conversion process. Natural moisture levels present in the product provide higher levels in syngas in the H2 specific. For this we adhere to humidity sensors (2.3.1). We also evaluate sample weight with dry and wet product during testing to record differences.

4.2.2. Particle size and distribution

For biomass chips, uniform particle size and distribution are important for feeding and processing, suppliers like Giusiano already give the product a small size of about 20 cm, but we with a shredder on the farm do other steps reducing to an ideal size of less equal 5 cm (2.1.1.). Distribution after shredding or not is carried out with sieves.

4.2.3. Apparent density

Biomass bulk density affects storage, transport and handling efficiency. Also during the tests we often measure it with known standard vessels, 0,25 Kg/l is a typical mean value found on post-shredding wood chips.

4.2.4. Ash content

The ash content, the residue remaining after combustion, affects the maintenance and operation of energy conversion systems. Using high temperatures, the ash fraction is insignificant (3%). On ash we have developed treatments described in point 1.4.

4.2.5. Calorific value

The calorific value, or energy content, of biomass is an important indicator on the performance of the single type of wood chips. Higher calorific values allow you to generate more energy from a given amount of biomass.

4.2.6. Chemical composition

The chemical composition, including the content of cellulose, hemicellulose, lignin and extractive matter, affects the behaviour of biomass during conversion processes. The chemical composition is analysed using various chromatographic gas analysis methods such as Soprane GC and SWG 100 MRU.

4.2.7. Contaminants and foreign materials

The presence of contaminants, such as stones or inert materials, can have harmful effects on conversion systems, causing wear, damage or operational interruptions. Visual inspections, combined with separation methods and sieves, ensure that the material is uniform.

4.2.8. Sustainability and traceability

The assessment of the sustainability and traceability of woody biomass involves the verification of its source, the guarantee that it comes from sustainably managed forests and the confirmation that the collection and processing comply with environmental standards. This assessment is typically conducted through documentation audits, certifications and audits.

5. IDENTIFICATION OF CRITICAL ISSUES IN BIOMASS TREATMENT USING GREEN PLASMA TECHNOLOGY

5.1 STRATEGIES FOR ENHANCING THE QUALITY OF WOOD CHIPS AND OPTIMIZING TREATMENT PROCESSES

In the context of biomass-to-energy conversion projects like those employing Green Plasma technology, the quality of wood chips and the efficiency of treatment processes are paramount. Implementing strategies to enhance wood chip quality and optimize treatment operations can significantly impact the system's overall performance, energy yield, and environmental sustainability.

5.1.1 Enhancing Wood Chip Quality

Selection and separation of raw materials: The selective supply of biomass from species with higher lignocellulosic content can improve the energy content of wood chips. This selection can be made by consulting our data on the Cloud, with this data we can make a correlation between the types of wood chips and the higher energy yield and have wanting a more accurate selection

Contaminant management: The implementation of robust screening and cleaning processes to remove contaminants, such as metals, stones and excessive bark, can prevent operational problems in the gasification system and improve the quality of the syngas produced.

5.1.2. Optimizing Treatment Processes

Real-time monitoring and adaptive control: integration of real-time monitoring systems in the plant to keep track of critical parameters such as origin, temperature and feed rate, along with adaptive control systems with the PLC , It can optimize the gasification process in response to changes in wood chip quality by adjusting blower set point with pressure or even gas output.

Improving raw material flexibility: the constant modification and improvement of the green plasma reactor design to adapt to a wider range of wood chip qualities can increase the flexibility and resilience of the system to the variability of raw materials, the study of the design aimed at the treatment of the reactor and always improving.

Syngas Cleaning and Conditioning: the implementation of filtering technologies such as scrubber or demister we have seen that are essential for the first skimming of any pollutants in the gas, In addition, we have also developed filtering stations on two lines with activated carbon or Cao and wanting also different that are chosen according to the need of treated wood chips.

Strategies of Co-feeding: Co-feeding options where lower quality biomass is mixed with higher quality raw materials and biomass or additives that can catalyse the gasification process or absorb contaminants can stabilize and improve the process of treatment.

Maintenance and downtime management: Establishing proactive maintenance protocols based on predictive analytics and ensuring fast response times for routine and unplanned maintenance can minimize downtime.

Collaboration between stakeholders: Collaboration with biomass suppliers, technology providers and research institutes can encourage continuous improvement of the quality of wood chips and optimization of treatment processes through shared knowledge.

5.2 DEVELOPMENT OF STANDARD PROCEDURES FOR BIOMASS PROVISION TO ENSURE COMPATIBILITY WITH GREEN PLASMA TECHNOLOGY

5.2.1. Logistics and transport

Efficient routing: development of efficient routing plans for transporting biomass from collection points to treatment plants, minimizing transit times and the carbon footprint associated with logistics.

Cargo Management: Standardize loading practices to maximize transport efficiency, prevent contamination during transit, and ensure secure biomass management.

Raw Material Flexibility Analysis: Regularly evaluate raw material flexibility of the Green Plasma system to adapt to changes in biomass quality and explore potential adjustments.

Adjustment of operational parameters: establish guidelines for the regulation of the operational parameters of Green Plasma technology based on the characteristics of input biomass, such as feed rate modulation, temperature settings and time settings.

Improvement and feedback report: We draw internal reports at each end of the test with feedback between the processes of biomass supply and the operation of the Green Plasma system and the conduct of the test and its results. Use operational data and performance metrics to continuously refine biomass treatment and management procedures.

Training and capacity building: Develop comprehensive training programmes for staff involved in biomass harvesting, pre-treatment and system operation to ensure compliance.

5.3 PREPARATION FOR FINAL PERFORMANCE ANALYSIS

The final analysis of the performance of a biomass to energy conversion system assesses the overall efficiency.Proper preparation for this analysis is essential to ensure that complete and accurate conclusions can be drawn:

5.3.1. Collection of basic data

Operational data: Compile complete operational data through internal reports and graph compilation from data automatically provided by the PLC that saves them through a datalogger covering the entire duration of the test, including the characteristics of the raw materials, any operational parameters of the system, power production with syngas levels, and any deviations from standard operating procedures.

Control Metrics: Establish control metrics against which the performance of the Green Plasma technology can be measured. This may include baseline data from conventional biomass treatment systems or theoretical models predicting expected outcomes.

5.3.2. System Calibration and Optimization

System Check-up: Conduct a thorough check-up of the Green Plasma system to ensure all components are functioning optimally. This includes reviewing sensor calibrations, plasma generator performance, and syngas cleaning and conditioning systems.

5.3.3. Analytical tools and methodologies

Analytical equipment calibration: Calibrate all analytical equipment and instruments that will be used in the final performance analysis, including gas analysers, calorimeters and emission monitoring equipment.

5.3.4. Regulatory and Environmental Compliance

Regulatory Checklist: Review all regulatory requirements and environmental compliance standards that the final performance analysis must adhere to, ensuring that all necessary permits and approvals are in place.

Environmental Monitoring Plan: Establish a comprehensive environmental monitoring plan to assess the impact of the system on air quality, water usage, and waste generation during the analysis period.

6. FRAMEWORK FOR EVALUATING GREEN PLASMA TECHNOLOGY'S PERFORMANCE IN DL.C7.3

6.1 OUTLINE OF ANTICIPATED ANALYSES AND COMPARISONS WITH EXISTING TREATMENT SYSTEMS

Differences already present are highlighted in the initial part of the deliverable Figure 1.3 and Section 1.3. This comparative approach provides a clearer understanding of the benefits of technology, potential areas for improvement and its overall impact on the energy landscape, For the purpose of continuous improvement, comparisons should always be present in the search for different or similar methods.

The analyses envisaged can be divided into several key areas:

6.1.1. Efficiency and productivity analysis

Energy conversion efficiency: measures the ratio of usable energy production to the energy content of incoming biomass, comparing it with conventional biomass gasification, combustion and other relevant technologies.

Efficiency and quality Syngas: Analyse the volume and calorific value of the syngas produced per unit of biomass, evaluating the consistency of the composition of the syngas and its suitability for various final applications.

Use of raw materials: Evaluate the ability of technology to process different types of biomass, including waste biomass with variable moisture content, size and composition, and compare this versatility to other systems.

6.1.2. Economic and operational profitability

Cost-effectiveness: Analyse the capital, operational and maintenance costs of the Green Plasma system related to energy production and compare these costs with those of established biomass treatment systems.

System reliability and maintenance needs: Evaluate the operational stability, maintenance frequency and downtime of the technology, comparing these operational aspects with those of other biomass treatment methods.

Scalability and Adaptability: Evaluate the potential for scaling up the technology for larger applications or adapting it for different settings, comparing this flexibility with that of existing systems.

6.1.3. Societal and Market Impact

Energy Independence and Security: Consider the technology's contribution to local energy production, reducing reliance on imported fuels, and compare this aspect with the impact of other biomass conversion technologies.

Contribution to Circular Economy: Assess how the technology promotes the use of waste biomass and contributes to waste reduction and resource recycling, comparing its effectiveness in supporting a circular economy with other treatment options.

6.1.4. Lifecycle and Sustainability Considerations

Lifecycle Analysis (LCA): Conduct a comprehensive LCA to understand the environmental impacts associated with all stages of the technology's lifecycle, from biomass sourcing to end-of-life disposal and compare these impacts with those of other biomass energy systems.

Alignment with Sustainable Development Goals (SDGs): Evaluate how the technology contributes to achieving various SDGs, particularly those related to clean energy, climate action, and sustainable industry, comparing its contributions with those of existing biomass treatment solutions.

6.2 SUMMARY OF INSIGHTS GAINED ON THE USE OF GREEN PLASMA TECHNOLOGY FOR FOREST WASTE TREATMENT

The exploration and application of Green Plasma technology in initiatives such as the GREENChainSAW4Life project have provided valuable information on its feasibility, efficiency and sustainability for the treatment of forest waste and its conversion into energy. This information contributes to an evolving understanding of how advanced gasification technologies can be integrated into biomass management and energy production systems.

6.2.1. High efficiency in energy conversion

Green Plasma technology In our demonstration campaign, achieved high energy conversion efficiencies by transforming forest waste into high-quality syngas. The intense heat and reactive environment of the reactor ensure the complete decomposition of the biomass components, making it a powerful source of energy for electricity generation.

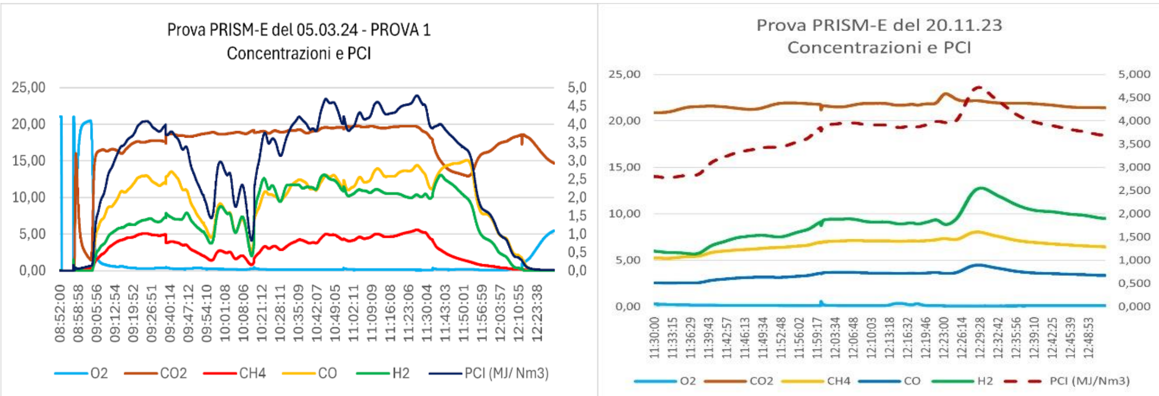


Figure.6.1. (E.s. Composition %Syngas)

6.2.2. Versatility in raw material handling

The technology demonstrates versatility in handling a wide range of biomass raw materials, including residues with high moisture content or irregular dimensions. This flexibility makes it valuable for managing different forest waste streams.

6.2.3. Reduced environmental impact

Environmental assessments show that Green Plasma technology minimizes emissions of pollutants and greenhouse gases compared to conventional combustion-based systems.

6.2.4. Contribution to Circular Economy

Green Plasma technology contributes to the circular economy by valorising renewable and underutilized forest waste. By converting waste into energy and useful by-products, it supports waste reduction, resource efficiency, and sustainable value chains.

6.2.5. Challenges and Opportunities for Improvement

Challenges such as feedstock pre-treatment and by-product management present opportunities for further research and development. Enhancing pre-treatment processes' efficiency and finding sustainable uses for by-products are areas for improvement.

6.3.6. Scalability and Broader Applications

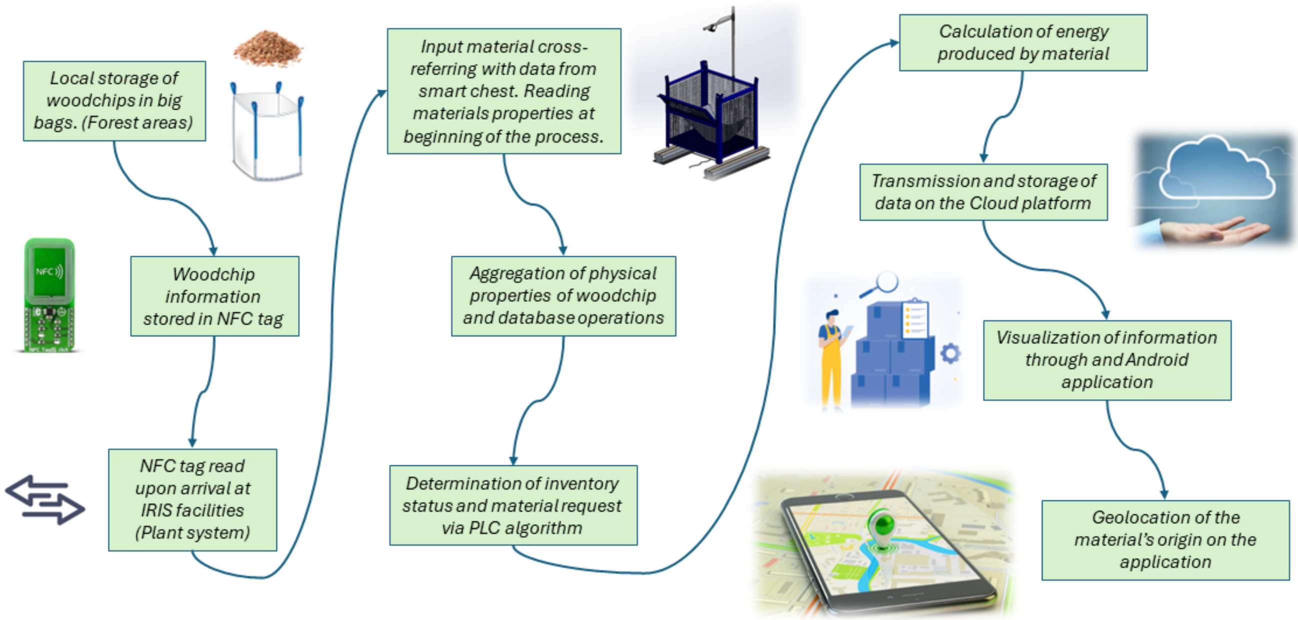
Insights highlight the technology's scalability, from small-scale applications in remote communities to larger industrial-scale facilities. Its adaptability to different contexts contributes to local energy resilience and sustainability, indicating broader applications beyond forest waste treatment.

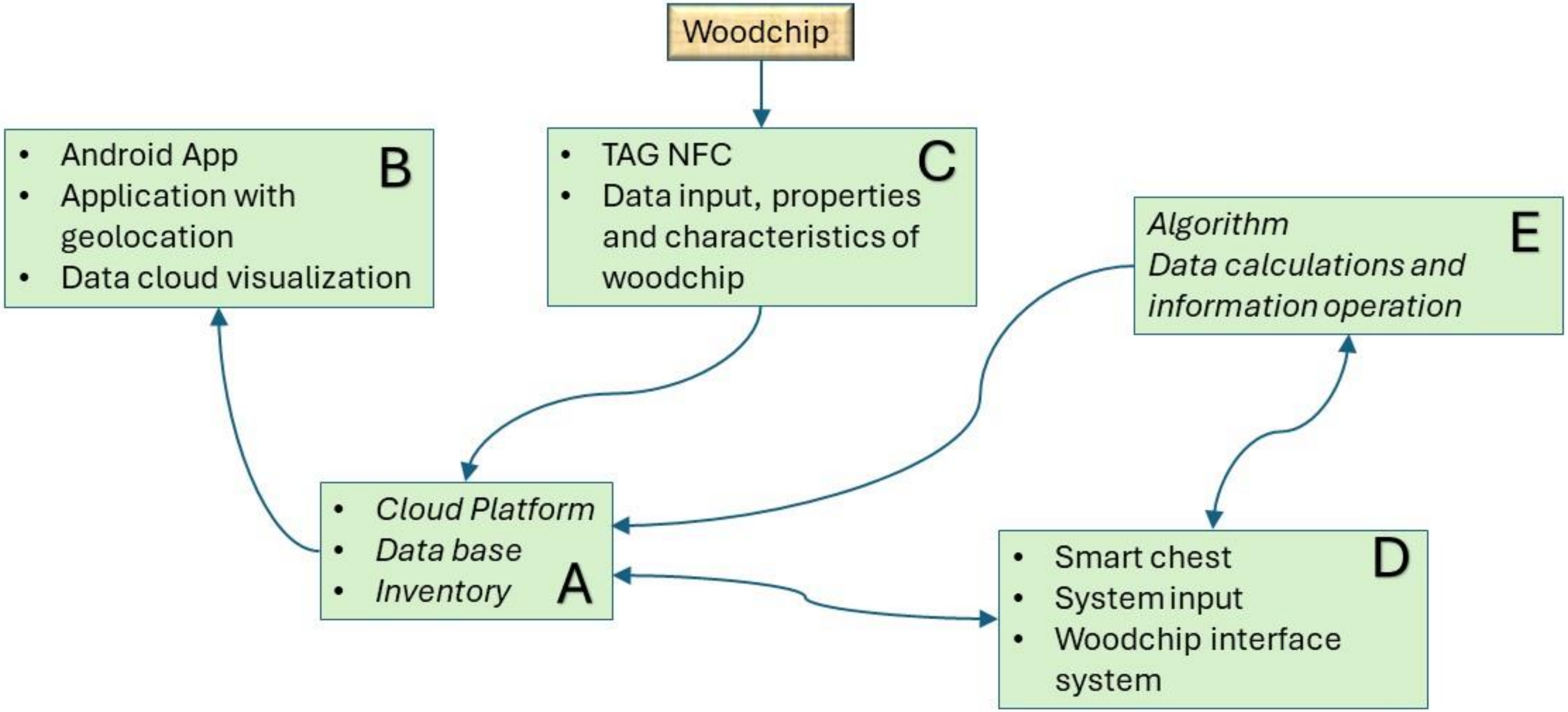
7. APPENDICES

7.1 TECHNICAL SPECIFICATIONS OF GREEN PLASMA TECHNOLOGY

Attachment CL7.2-01-TECHNICAL SPECIFICATIONS OF GREEN PLASMA TECHNOLOGY.pdf

7.2 DIAGRAM OF LOGISTIC PROCESS

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