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2nd NEWSLETTER

JANUARY 2025

CRONUS

CAPTURE AND REUSE OF BIOGENIC GASES FOR NEGATIVE-EMISSION – SUSTAINABLE BIOFUELS

TECHNICAL PROGRESS

Development of optimized biological CO_2 hydrogenation process

In the context of shedding light on the biomethanation process and optimize its efficiency under various operating conditions, the trickle bed reactor (TBR) set-up (Fig. 1) was selected, as it is considered one of the most promising configurations. These reactors are filled with a packing material that supports the immobilization of microorganisms through biofilm formation. To evaluate process flexibility, the feedstock supply was gradually increased (i.e., reduced Gas Retention Time – GRT) to determine the maximum gas flow that could be processed while maintaining high biomethanation efficiency. The feedstock strategy is shown in Fig. 2. Three different packing materials—K1 micro Raschig rings, activated carbon pellets, and biochar (Fig. 3)—were tested to assess their impact on process performance. K1 micro Raschig Rings proved to be the most effective, maintaining high methane purity (>95%) down to a GRT of 25 minutes, whereas the other materials only sustained efficiency until a GRT of 1 hour.

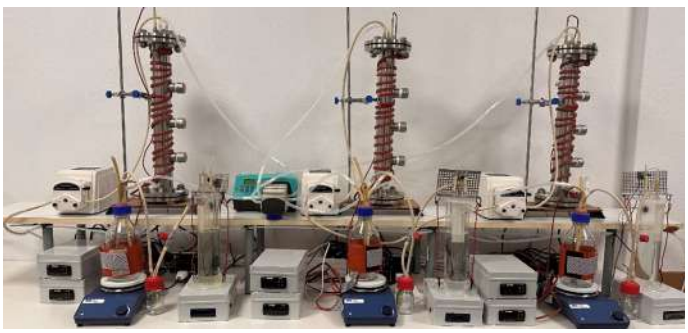

Figure 1.
Reactor configuration for the investigation of biomethanation flexibility

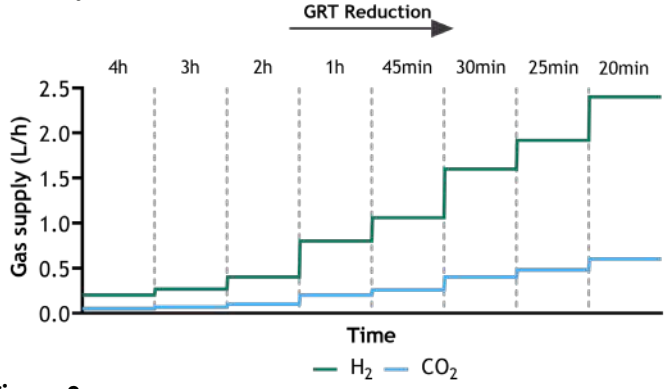

Figure 2.
Feeding strategy for the three TBRs filled with different packing materials.

Figure 3.
The packing materials were explored for the biomethanation process. a) K1 micro Raschig Rings, b) activated carbon pellets and c) biochar.

Additionally, the biomethanation process was tested under intermittent hydrogen supply to simulate real-world conditions where renewable energy may not consistently power the water electrolyzer for hydrogen generation. The feedstock strategy for this phase is illustrated in Fig. 4. Both reactors, filled with activated carbon pellets and K1 Raschig Rings, showed remarkable flexibility, resuming methane production after starvation periods of up to 5 weeks, indicating high process resilience and microbial tolerance to feedstock interruptions.

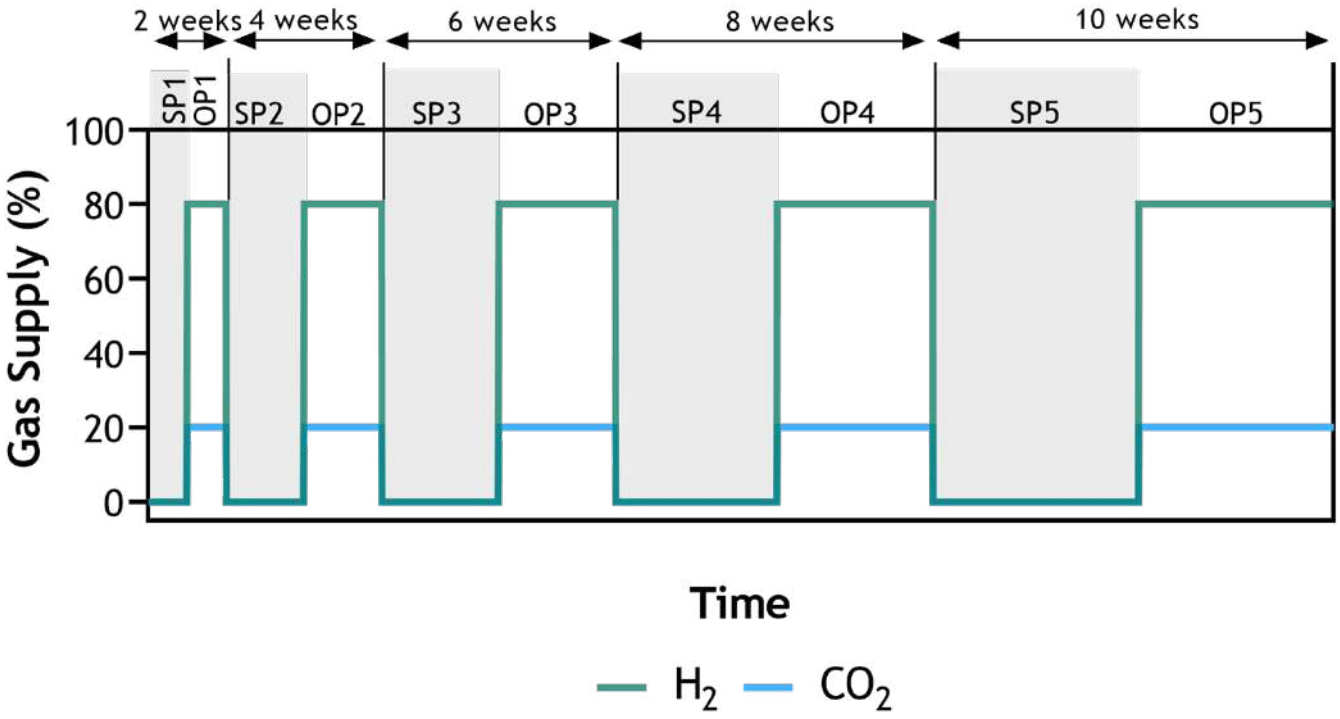

Figure 4.
Feeding strategy for the investigation on the impact of intermittent gas supply in the biomethanation process.

Progress of FP1

LEAD PARTNER
NTUA

LOCATION
LAVRION TECHNOLOGICAL & CULTURAL PARK

AIM
CAPTURE AND UTILISE CARBON DIOXIDE PRODUCED FROM A BIOFUELS BIOREFINERY THAT INCLUDE BIOMASS COMBUSTION, ETHANOLIC FERMENTATION AND ANAEROBIC DIGESTION VIA AUTOTROPHIC ALGAE GROWTH

Figure 5.
Pond parts shipped to Lavrion, Greece

Figure 6.
One pond installed in Lavrion, Greece

The design, construction and installation of FP1 has started. The main stages of FP1 include the efficient dissolution of CO2 into aqueous solution, ensuring adequate transfer of CO2 from the gas phase to the aqueous phase by enzymatic CO2 capture in the bed reactor, the cultivation of algae on the derived solution inside a raceway pond and a sedimentation talk for each pond, and the valorisation of the produced algal biomass in the existing biorefinery aiming to maximise biofuels production and resource utilization and extraction.

Civil works necessary to accommodate FP1 in NTUA's Lavrion Culture and Technological Park (LCTP), Attica, Greece are in progress. Regarding the CO2 scrubber, raw designs are ready. The prototype scrubber will have a total installed power of 1.9kW and will be installed until March 2025. Regarding the algae cultivation, the equipment selected consists of 4 ponds (9 m2 each) with control and sensor system. All ponds are designed, produced and shipped to Greece. The 1st pond is installed and the installation of the rest of the ponds is being finalised.

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Progress of FP2

LEAD PARTNER
ELGO

LOCATION
ELGO-DIMITRA'S THERMI-THESSALONIKI CAMPUS

AIM
UTILIZE CO_2 FROM BIOGAS AND HYDROGEN GENERATED THROUGH WATER ELECTROLYSIS FOR THE PRODUCTION OF BIOMETHANE AS THE FINAL PRODUCT.

Figure 1. a) Pilot scale anaerobic digester and **b)** Control panel of the unit.

Figure 2. a) Pilot scale biomethanation unit and **b)** K1 micro Raschig Rings which were selected as the most suitable material to fill the trickle bed reactor

The system involves two pilot bioreactors and an electrolyzer, interconnected for efficient operation. The biogas will be produced by an existing pilot scale anaerobic digester (Fig. 1a,b) with a working volume of 1m^3, located at ELGO-DIMITRA's Thermi-Thessaloniki campus. The biomethanation unit (Fig. 2a) has already been constructed. The "heart" of the unit is the trickle bed reactor, which is a custom-made reactor, designed by ELGO's team with a total volume of 100L. According to the results of the laboratory-scale study, K1 micro Raschig Rings have been selected as the filling material for the trickling bed reactor to immobilize the microorganisms pertinent to the process. The reactor is currently undergoing gas-tightness testing.

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Progress of FP3

LEAD PARTNER
BTPRO

LOCATION
COPENHAGEN, DENMARK

AIM
GENERATE ADDITIONAL VALUE BY IMPROVING THE WASTE CONVERSION EFFICIENCY AND BIOGAS PRODUCTION OF CONVENTIONAL BIOGAS PLANTS THROUGH THE SYNGAS BIOMETHANATION PROCESS CONTEMPLATED.

DTU currently focus on finalizing the pilot scale reactor set-up for Functional Prototype 3, which will upgrade syngas, a gaseous mixture of mainly H_2, CO and CO_2, into biomethane with the aid of exogenous renewable H_2. The pilot reactor of 100 L has already been transferred to the facilities of DTU, and BiotechPRO and DTU are working together on working on the last details before starting operation.

Picture 2.
Pilot Trickle Bed Reactor set-up in the container.

Picture1.
Moving DTU pilot Trickle Bed Reactor from Risøe to DTU facilities.

Progress of FP4

LEAD PARTNER
CIRAD

LOCATION
ENERGY PLATFORM OF CIRAD – MONTPELLIER - FRANCE

AIM
CONVERT BIOMASS, AGRORESIDUES AND DIGESTATES INTO (I) BIOCHAR (SOLID CARBON PRODUCT) FOR AGRONOMIC AND CARBON SINK APPLICATIONS, AND (II) GASEOUS CO-PRODUCTS FOR ENERGY APPLICATIONS

An existing pyrolysis pilot unit based at CIRAD's energy platform in Montpellier, France, has been adapted and improved to meet this objective.

The pilot consists of a vertical cylindrical metal reactor approximately 1 m high and 0.3 m in diameter. This reactor is electrically heated over its entire height by 3 blocks of electrical resistors. The maximum treatment temperature is 1000°C, but the project provides for a reasonable temperature range between 300°C and 800°C. Each block is individually controlled via a PID and connected to control-command software (developed at CIRAD). This configuration allows temperature gradients to be imposed throughout the reactor, if required. The reactor can be used in two distinct modes (batch mode or continuous mode) depending on the nature of the raw material. The raw material occupies the entire internal volume of the reactor (70 l). Depending on its density and particle size, the raw material may flow naturally from top to bottom during pyrolysis, in which case continuous mode is used. In this mode, the raw material is fed continuously by a screw feeder. The biochar is collected, also continuously, at the bottom by another auger system.

Batch mode is used for complex biomasses that do not allow the feedstock and biochar to flow. This is the case for biomasses with low density and complex granulometry (such as straw or sawdust). Four metal baskets are then filled with the raw material and introduced into the reactor at the bottom. The reactor is then closed at both ends and started up. The baskets are removed after pyrolysis and cooling of the furnace.

The reactor can be supplied with either nitrogen or CO_2 carrier gas, or both at the same time (for biochar activation). It can also be run without carrier gas if required.

In all cases, the gaseous by-products are collected in the upper part of the furnace and sent to a post-combustion chamber for burning. The first tests were carried out on rice husks in batch mode without any particular difficulty.

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The figure 1 shows the principle of the system and an overview of the FP4.

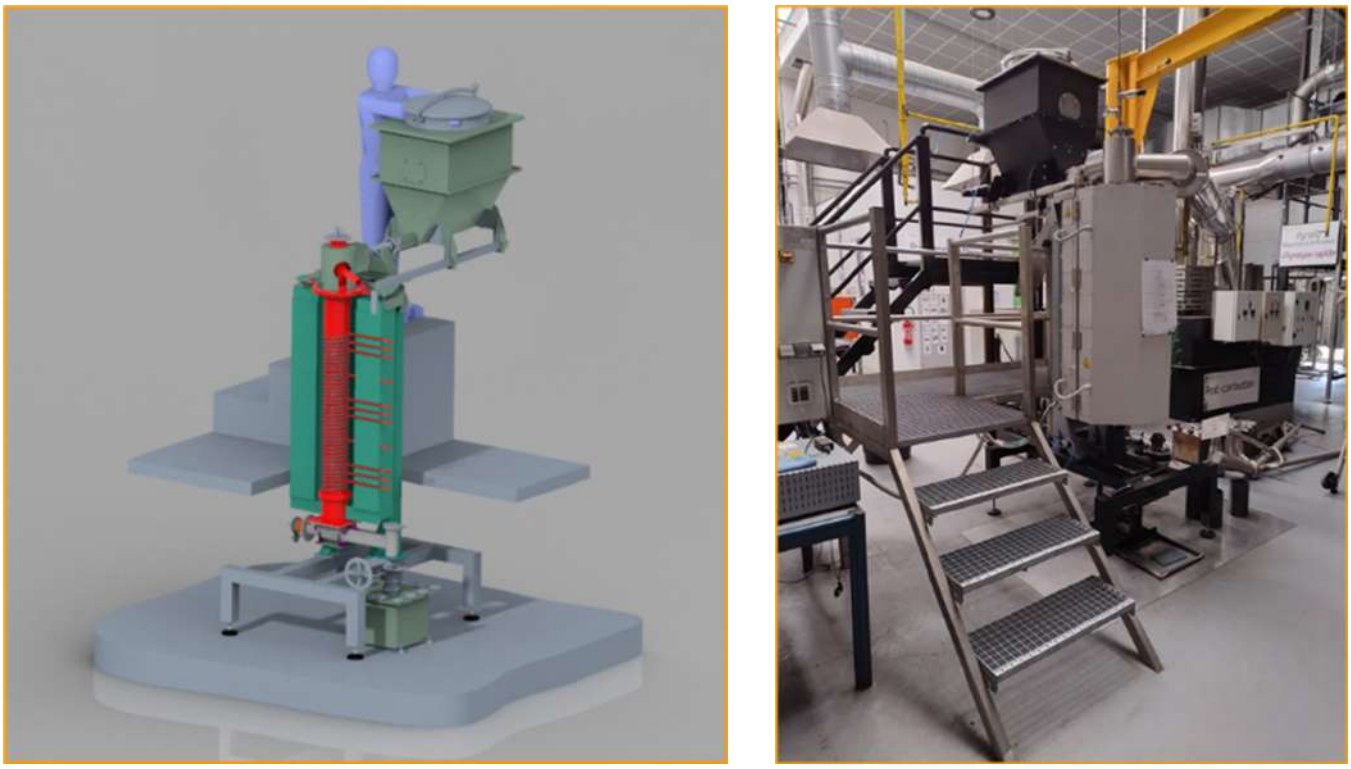

Figure 1 : Principle of the FP4 and overview of the pilot plant

Figure 2 shows the reactor with its improvements to the continuous feed system for raw materials and biochars, and gases outlet connection with a combustion chamber.

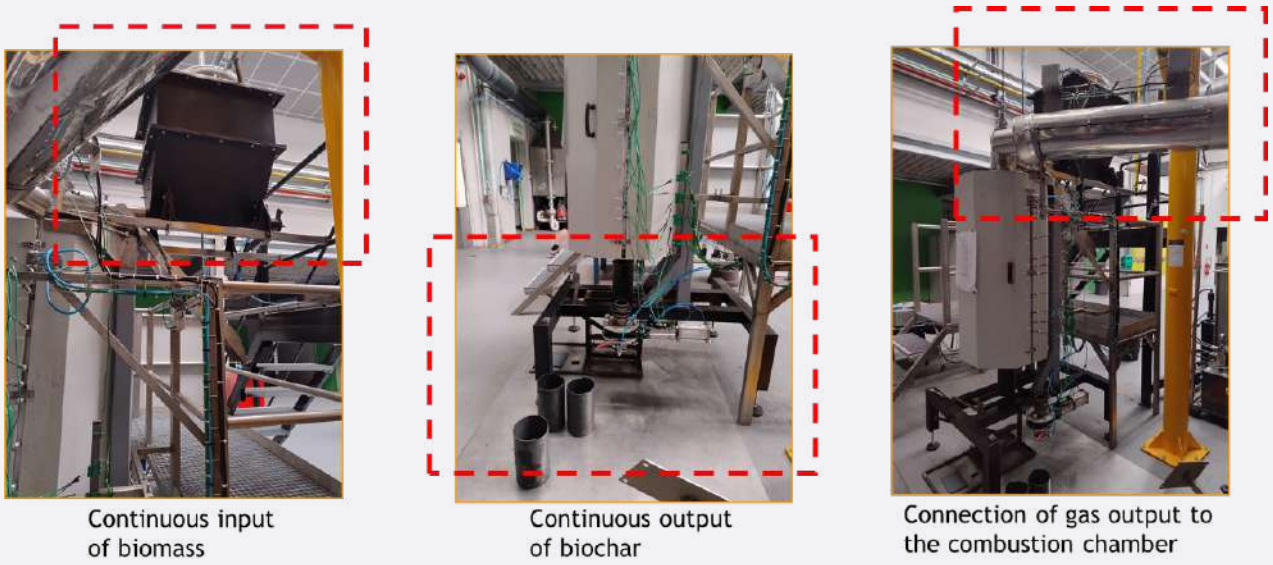

Figure 2: Feeding system and gas connection with external combustion chamber of the FP4

Progress of FP5

LEAD PARTNER
CARTIF

LOCATION
CARTIF, TECHNOLOGY PARK, BOECILLO, VALLADOLID, SPAIN

AIM
DESIGN, CONSTRUCTION AND INSTALLATION: AN EXISTING TWO-PHASE AD PILOT PLANT WILL BE RETROFITTED IN TERMS OF COUPLING A TAILOR-MADE MEC SYSTEM IN ONE OF THE DIGESTERS

In Functional Prototype 5, a microbial electrolysis cell is coupled with a two-phase anaerobic digestion pilot plant. Anaerobic digestion is a natural process where microorganisms break down organic matter into methane and carbon dioxide. Additionally, hydrogen will be produced by the microbial electrolysis cell. This hydrogen will serve as a substrate for hydrogenotrophic methanogens which convert CO_2 together with the hydrogen in methane.

There are several design options for the AD-MEC system, it can be configured "in-situ" or "ex-situ," with in-situ setups commonly enhancing methane yield by enriching electroactive bacteria and hydrogenotrophic methanogens. Ex-situ systems act as post-treatment units, boosting biodegradability and energy recovery. As the objective of CRONUS is to capture and utilize CO_2 FP 5 will be designed as in-situ AD-MEC system.

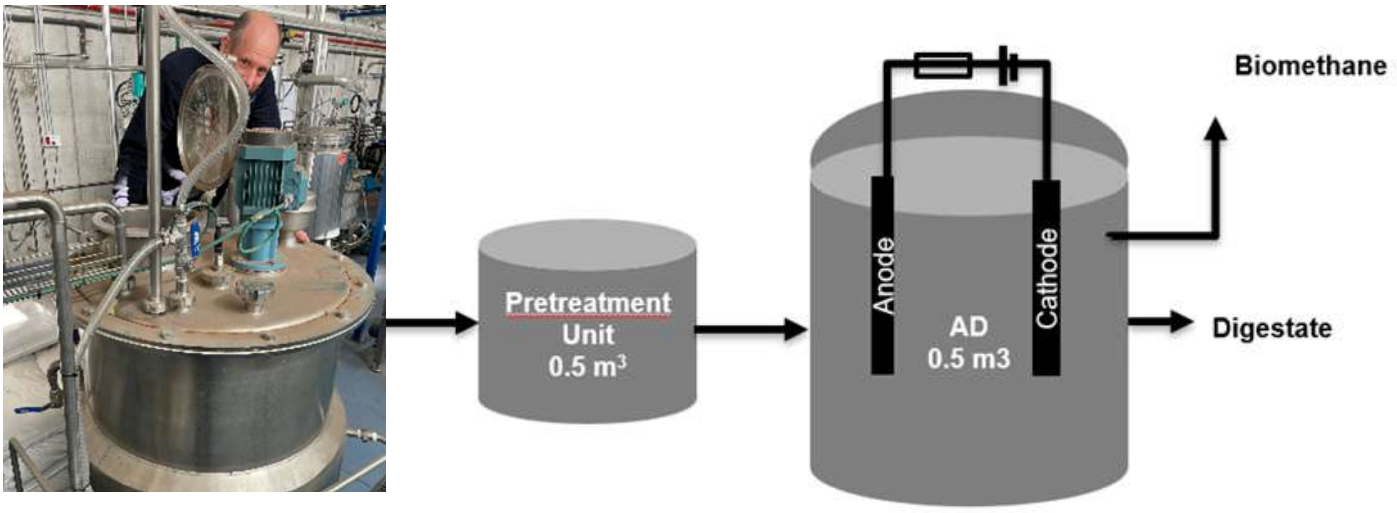

Figure 1: Schematic representation of in-situ configuration of FP5 and a picture of the AD to be retrofitted

The AD to be retrofitted is selected and offers are being evaluated. For the integration of the microbial electrolysis cell in the existing AD plans are made to develop an electrode module that contain the electrodes that can be placed in the AD.

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Stakeholders' engagement & involvement

To facilitate stakeholder engagement and foster collaboration, Communities of Practice (CoPs) have been formed around each Functional Prototype (FP). These CoP meetings serve as platforms to bring together various stakeholders to discuss challenges, opportunities, and technological advancements in the CRONUS project. Below is an overview of the CoP meetings organized for FP1 to FP5, including their objectives, processes, and outputs.

CoP Meeting for FP1

DATE
APRIL 4, 2024

TYPE
IN-PERSON

LEAD
PROF. DIMITRIS MALAMIS
PROF. MARIA LOIZIDOU (NTUA)

Objective

The primary objective was to establish the CoP for FP1, which focuses on the capture and use of CO_2 from biofuel production. The meeting aimed to introduce the FP1 technological solution, identify barriers to the technology's adoption, and enhance social acceptance through stakeholder engagement.

Process

The meeting involved a presentation of the pilot system developed by NTUA, followed by discussions on the barriers and opportunities for integrating biogenic CO_2 into the biofuels value chain. Participants from various sectors including industry, academia, and civil society were engaged through presentations and round-table discussions.

Outputs

Key barriers identified include economic uncertainty, lack of a legislative framework, and technological maturity concerns. Solutions proposed included financial incentives, legislative changes, and awareness campaigns. The CoP successfully brought together stakeholders and initiated conversations on improving the FP1 prototype's market readiness.

CoP Meeting for FP2

DATE
MAY 14TH, 2024

TYPE
IN-PERSON

LEAD
DR PANAGIOTIS KOUGIAS, DR MARIA GASPARI (ELGO-DIMITRA)

Objective

The goal of the meeting was to introduce FP2, which focuses on biomethane production using biogenic CO2. The session aimed to identify technological barriers, assess the socio-political landscape, and facilitate stakeholder discussions on the future implementation of FP2.

Process

Following the introduction of the CRONUS project and FP2's technological solution, stakeholders were engaged in open discussions on the barriers and opportunities of integrating biogenic CO_2 into the biofuels value chain. A questionnaire was provided to capture detailed stakeholder feedback on issues such as market uncertainty, technological gaps, and regulatory challenges.

Outputs

Key barriers identified include economic uncertainty, lack of a legislative framework, and technological maturity concerns. Solutions proposed included financial incentives, legislative changes, and awareness campaigns. The CoP successfully brought together stakeholders and initiated conversations on improving the FP1 prototype's market readiness.

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CoP Meeting for FP3

DATE
APRIL 12TH, 2024

TYPE
ONLINE

LEAD
DR ANTONIO GRIMALT ALEMANY (DTU), DR GONZALO GAMBOA & BERTA ROSET (UAB) - PhD (c)

Objective
The aim of the meeting was to introduce FP3, which focuses on syngas biomethanation. The meeting sought to discuss technological barriers, market integration challenges, and stakeholder concerns related to the use of syngas in biofuel production.

Process
Presentations covered the laboratory results of FP3's syngas biomethanation and its potential scale-up. Stakeholders were engaged through an interactive session using Mentimeter, focusing on the barriers and opportunities for integrating biogenic CO_2 into biofuel production.

Outputs
While the meeting was productive, it was noted that more participation from civil society and public administration was needed. Nevertheless, the CoP identified key technological barriers and discussed potential pilot-scale configurations for FP3.

CoP Meeting for FP4

DATE
APRIL 5TH, 2024

TYPE
IN-PERSON

LEAD
CIRAD

Objective
The aim of the meeting was to introduce the process used by FP4, that is the pyrolysis conversion. Solid residues (like biomass, agro-residues, etc.) are converted by heat treatment at very high temperature and absence of oxygen (400–800°C) into various products, the main ones being porous solid rich in carbon (biochar) and light and heavy fuel gases.

Process
Attending participants were presented FP4 process by presentations and the relative video. At the end of the meeting a visit to the CIRAD pyrolizer allowed for onsite further discussion.

Outputs
In summary the major outputs of the 1st FP4 CoP meeting emphasized by the participants were: the barriers in the availability of raw materials in terms of volume and location leading to increased competition and or high transportation costs, the requirement for a sustainable and stable value chain focusing on the innovation of FP4 to take advantage of the new niche created as a promissing and attractive opportunity.
The significance of financial viability was particularly stressed as Carbon credit (linked to biochar) is not sufficient motive for industrialists (e.g. Total). The different uses for biochar were widely discussed for the use of sustainable construction and if well stabilised for road works.

Participants noted intensively the absence of a structured and stable biochar sector in France.

CoP Meeting for FP5

DATE
APRIL 20, 2024

TYPE
IN-PERSON

LEAD
CARTIF-UAB

Objective

The CoP for FP5 was established to discuss the challenges and opportunities in integrating biogenic CO_2 into the biogas/biomethane value chain. The primary focus was to gather insights from stakeholders regarding feedstock, technological, and political-administrative barriers.

Outputs

Key outcomes of the workshop included discussions on the availability of raw materials, the need for regulatory frameworks, and the potential for scaling up FP5 technologies. The meeting emphasized the importance of stakeholder networking and collaboration.

Process

A workshop was conducted where participants, categorized into different groups, discussed specific challenges. The discussions were facilitated through a series of group activities, where stakeholders shared their ideas on overcoming the identified barriers.

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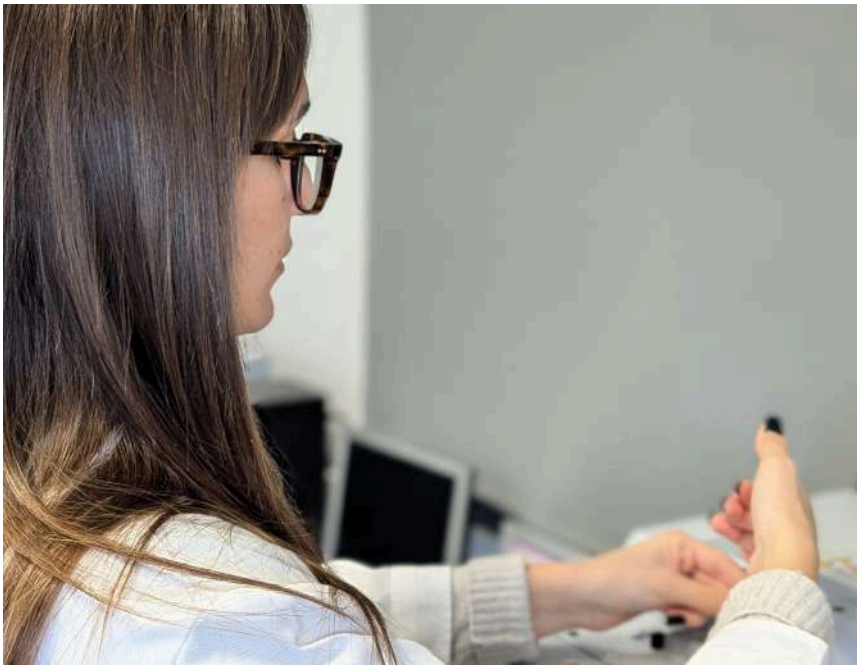

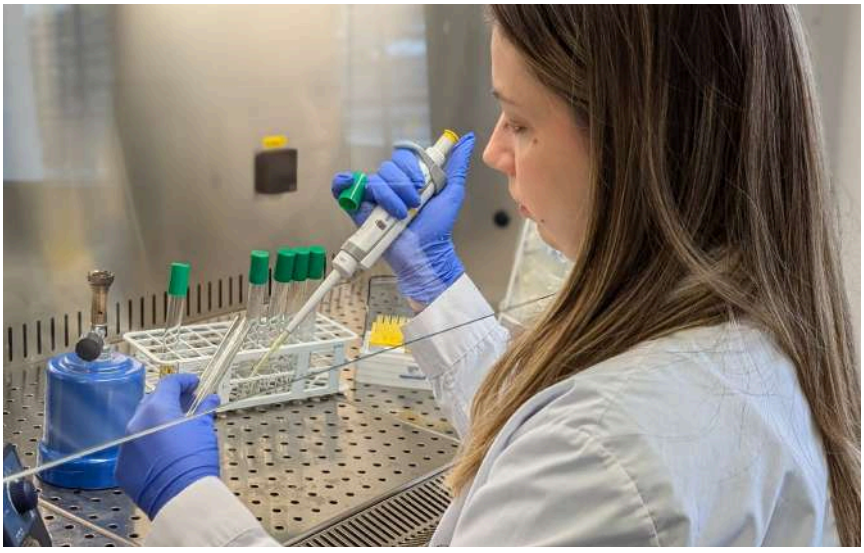

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1st Annual Project Meeting in Barcelona, UAB Campus, February 2023

The 1st Project Annual meeting was held in Barcelona, at the UAB campus, with the presence of all partners representatives, over a two-day event during which the project progress was discussed.

UAB Campus, Barcelona

CIRAD Lavalette C. Cornu, CIRAD

Upcoming events

2nd Annual Project Meeting in Montpelier, France at CIRAD permises on February 6th & 7th , 2025.

12th International Conference on Sustainable Waste Management, Paphos, Cyprus, 25th – 28th June, 2025.

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