CO2 to CH4 Life

With the contribution of the LIFE Programme of the European Union
LIFE20 CCM/GR/001642

DEMONSTRATION OF A MOBILE UNIT

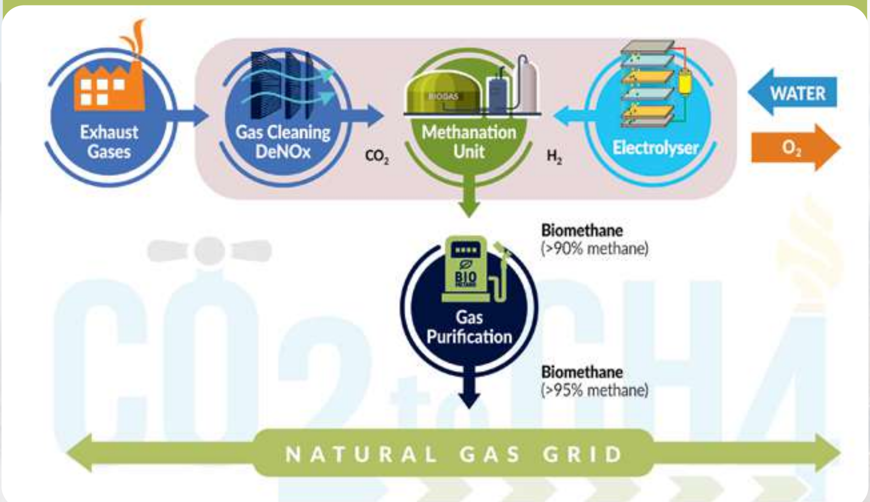
FOR HYDRID ENERGY STORAGE BASED ON CO_2 CAPTURE AND RENEWABLE ENERGY SOURCES

4TH NEWSLETTER 2024

THE PROJECT

LIFE CO2toCH4 aims to develop and demonstrate an innovative, integrated, and sustainable industrial process for simultaneous energy storage and CO_2 capture and utilization (CCU). The ultimate goal of the project is to construct, test and operate (TRL8) a smart mobile unit for hybrid energy storage able to be installed in remote energy systems that commonly have low capacity (e.g. remote areas or islands that are not connected to the central energy grid). The technology innovation relies on the fact that the RES (Renewable Energy Sources) to be used for water electrolysis and subsequently, the produced H_2 will be biologically converted into methane (as a non-fossil biofuel) together with CO_2, which will be captured from exhaust gases with a two-stage membrane separation process.

LIFE CO2toCH4 Mobile Unit for Hybrid Energy Storage



PROJECT BENEFICIARIES

PPC Renewables

ARISTOTLE UNIVERSITY OF THESSALONIKI

ELGO - DIMITRA
HELLENIC AGRICULTURAL ORGANIZATION - DIMITRA

NEVIS
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Public Power Corporation

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TECHNICAL PROGRESS

PROTOTYPE PILOT METHANATION UNIT FOR THE UTILISATION OF CO_2: A SUCCESSFUL FIRST YEAR OF OPERATION

The prototype pilot methanation unit which has been designed, constructed, and operating in Hellenic Agricultural Organisation – DIMITRA, has successfully completed its first year of operation! This unit, part of the "**LIFE CO2toCH4**" project, aims to convert CO_2 into biomethane—a renewable energy source—thereby reducing net CO_2 emissions.

During this initial year, the project team meticulously designed the operational strategy for the pilot unit to achieve high biomethane production efficiency. This was done by gradually reducing Gas Retention Time (GRT) and closely monitoring daily performance (***Figures 1*** and ***2***). Key data points such as output gas composition (CH_4, H_2, CO_2), volatile fatty acids (VFAs) concentration, pH levels, and nutrient concentration were monitored to ensure optimal performance.

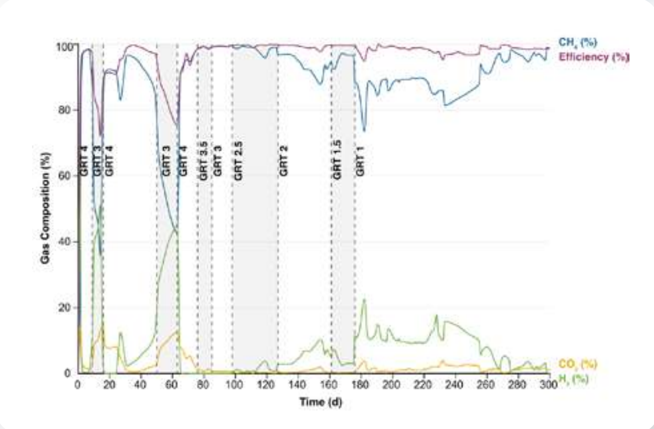

Figure 1: Output gas composition of the pilot unit during different GRT operation phases.

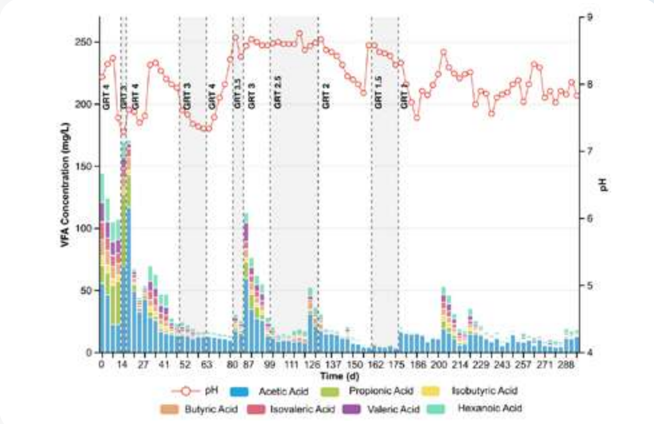

Figure 2: Stacked bar-plot of individual VFA concentrations (mg/L). The red line illustrates the pH values.

The pilot scale biomethanation system demonstrated remarkable efficiency and adaptability. It maintained high CH_4 output (over 95%) under various operational conditions and successfully utilized more than 250 kg of CO_2 as feedstock in the biomethanation process (***Figure 3***). The highest recorded Methane Production Rate was 4.65 $LCH_4/(LR \cdot d)$, highlighting the effective gas-liquid mass transfer and suggesting the potential for scaling up the system for larger applications.

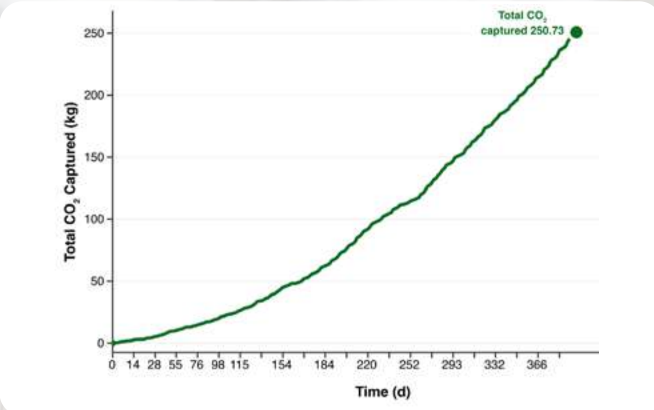

Figure 3: Total CO_2 captured during pilot unit operation.

Exceeding initial expectations, this pilot unit operation provides a deeper understanding of the system's capabilities and potential. It also provides greater confidence in the technology, paving the way for its application in larger-scale settings, such as the installations at the PPC Power Plant of Agios Dimitrios.

This milestone not only underscores the project's success but also marks a significant step forward in utilizing CO_2 for renewable energy production, contributing to global efforts in reducing carbon emissions.

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REVOLUTIONIZING HYDROGEN SUPPLY: ADVANCED PEM ELECTROLYSIS SOLUTION

The process of producing hydrogen is not complicated. Water electrolysis (H_2O) is a process, where electrical energy derived mainly from Renewable Energy Sources (RES) is used to decompose water into hydrogen (H_2) and oxygen (O_2), according to the following simple chemical equation:

$$2H_2O \rightarrow 2H_2 + O_2$$

Water electrolysis can be classified into three types, based on the selection of electrolyte and operating conditions, but the operating principle is the same in all these cases. During water electrolysis, water is decomposed into its constituent gas elements, H_2 and O_2, by providing an electric current supply. At the cathode, hydrogen ions (H_2) are reduced to H_2, which is considered as the reduction half-reaction. At the anode, H_2O is oxidized towards O_2 and H_2, which is the respective oxidation half-reaction.

These processes are described by the following reactions respectively:

$$2H^+(aq) + 2e^- \rightarrow H_2(g)(\text{cathode})$$

$$2H_2O(liq) \rightarrow O_2 + 4H^+(aq) + 4e^-(\text{anode})$$

The three mentioned methods of electrolysis are:

(i) Alkaline Water Electrolysis (AWE), where an aqueous solution of KOH or NaOH is used as the electrolyte to accelerate the process and increase its efficiency

(ii) Proton Exchange Membrane Electrolysis (PEM), which was selected in the case of LIFECO2toCH4 project, as described below, and

(iii) Solid Oxide Electrolysis (SOE), as its name suggests, uses solid oxides as electrolytes at the high temperatures of 800-1000°C.

In PEM electrolytic devices, there is a polymer membrane that allows only protons to pass through it. The reactions that take place within these devices are as follows:

$$H_2O \rightarrow ½\, O_2 + 2H^+ + 2e^-(\text{Anode})$$

$$2H^+ + 2e^- \rightarrow H_2(\text{Cathode})$$

The anode electrode in PEM electrolytic devices usually consists of noble metal oxides, such as iridium oxide (IrO_2), or ruthenium oxide (RuO_2), or proper alloys of these metals. Similarly, the cathode electrodes are made from platinum (Pt) often mixed with carbon to improve their performance. The polymer membrane has a strongly acidic character, due to the presence of sulfonic acid (SO_3H) functional groups. These groups are responsible for the conductivity of H_2 through an ion exchange mechanism (Kumar & Himabindu, 2019).

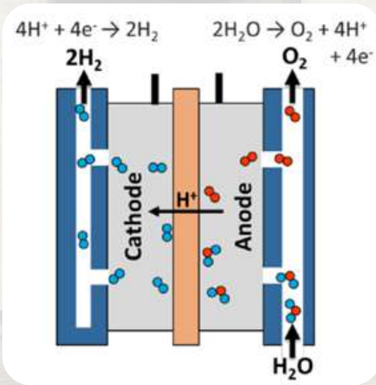

Figure 4. Schematic Diagram of a Proton Exchange Membrane Electrolysis Setup (Ursua A. et al., 2012).

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REVOLUTIONIZING HYDROGEN SUPPLY: ADVANCED PEM ELECTROLYSIS SOLUTION

Advantages of PEM electrolysis
Compact system design
High hydrogen production rate
High hydrogen purity (99.99%)
High energy efficiency (80–90%)

Table 1. PEM electrolysis pros.

Table 1 presents the specific advantages of H_2O electrolysis, when using a proton exchange membrane.

For the **LIFE CO2toCH4** project, the PEM QL-2000 (Nafion PFSA membrane) was selected (***Figure 5***). AUTH team prepared an instruction manual for the operation of specific electrolyzer along with the respective manufacturer's manual. On the front panel, the H_2O content level and the apparatus's supply rate (ml/min) are displayed. Additionally, an analog manometer is included for safety and to monitor the device's proper functioning.

Figure 5. Front view of the apparatus.

This setup received by the AUTH team, underwent several laboratory tests (***Figure 6***), where comparisons between different operating conditions performed, following the provided information from manufacturer. Specifically, measurements taken of the generated gas (H_2) and the resulting pressure (to ensure it corresponded with the apparatus's manometer). Additionally, several safety checks conducted accordingly, checking for gas leaking.

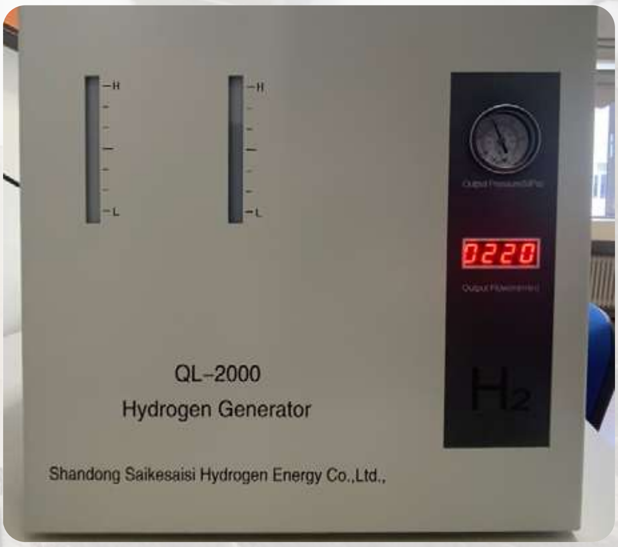

Figure 6. Photos of the apparatus in operation for the production of 220 mL/min H_2 with an output pressure of 4 bar.

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After its initial/preliminary operation, the apparatus transferred to the Agios Dimitrios Thermal Power Plant, where its connection with the membrane gas separation system is shortly expected (***Figure*** *7*).

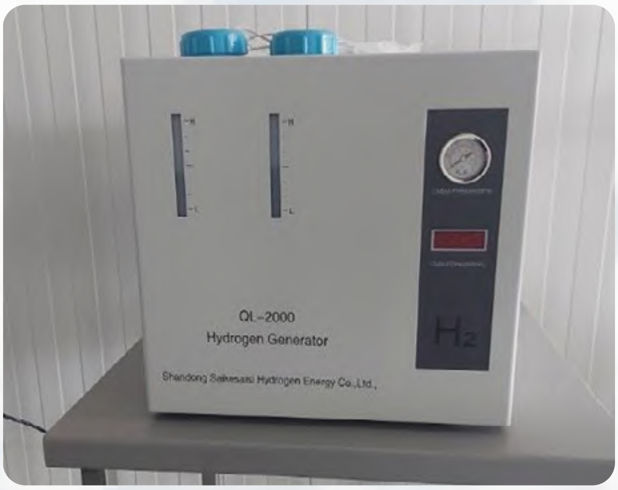

Figure 7. PEM electrolyser in Agios Dimitrios Power Plant.

FIRST PART OF THE PILOT UNIT ON SITE INSTALLATION

On April 30, 2024, the electrolyzer (part of the pilot unit) has been installed at the premises of Agios Dimitrios PPC Power Plant! The electrolyzer as part of the mobile hybrid energy storage system of the LIFE CO2toCH4 project, will be used to produce pure hydrogen (H_2), through electrolysis of water, which will then be fed to the methanation unit. The entire process was supervised by the project coordinator Dr. Apostolos Antoniadis (PPCR), Prof. Anastasios Zouboulis (AUTh), Dr. Froso Peleka (AUTh), Alexandros Chatzis (AUTh), Emmanouil Sakalis (PPC), Evaggelos Papazisis (PPC) and Helen Partheniou (PPCR).

The rest of the equipment is anticipated to be installed within the next months!

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MEETINGS & EVENTS

Student Visit At Agios Dimitrios, PPC Power Plant At Ptolemaida Mines

On April 22, 2024, students of the **26th Experimental Junior High School of Athens** visited the premises of Agios Dimitrios, PPC Power Plant at Ptolemaida Mines. The students had the opportunity to learn about **LIFECO2toCH4** project, discuss with members of PPC and PPCR and visit the site where the mobile hybrid energy storage system will be installed. In the frame of living labs, Helena Partheniou from PPCR, presented the main objectives and scope of the LIFECO2toCH4 project and how it is related to both National and European goals for decarbonization and exploitation of renewable energy sources, as well as the basic idea of the operation of the mobile hybrid energy storage system. Dr. Christos Roumpos with the contribution of Mr. Tryfon Barbas from PPC, made a presentation of the activities of PPC in the Lignite Center of Western Macedonia and how LIFECO2toCH4 project is related with PPC's strategy for the transition of the Western Macedonia Region to a post-lignite era.

The event was held in the presence of the project coordinator Dr. Apostolos Antoniadis (PPCR), while Petros Kostaridis (PPC), Emmanouil Sakalis (PPC), Evaggelos Papazisis (PPC) and people working in the Lignite Center of Western Macedonia were also present.

PUBLICATIONS

1. From microbial heterogeneity to evolutionary insights: A strain-resolved metagenomic study of H_2S-induced changes in anaerobic biofilms (*https://doi.org/10.1016/j.cej.2024.149824*)
2. Decipher syntrophies within C_2-C_4 organic acids-degrading anaerobic microbiomes: A multi-omic exploration (*https://doi.org/10.1016/j.cej.2024.151390*)

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CO2toCH4 BENEFICIARIES

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CO2toCH4 SUMMARY PROJECT DATA

Total Eligible Project Budget: 3,888,985 Euro
Project Implementation period: 4 years
EU financial contribution requested: 2,138,941 Euro
(= 55.00% of total eligible budget)

The project implementation started in October 2021 and it is expected to be completed by September 2025, in selected regions of Greece and Italy.

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WEBSITE

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The project is co-funded by LIFE, the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU.