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DEMONSTRATION OF A MOBILE UNIT

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

5TH NEWSLETTER
2025

PIONEERING CO2toCH4 BIOMETHANATION AND HYBRID ENERGY STORAGE AT AGIOS DIMITRIOS POWER PLANT

The LIFE CO2toCH4 project has reached a major milestone in advancing sustainable technology for both carbon capture and renewable energy storage. Building on the successful operation of the prototype pilot methanation unit at the Hellenic Agricultural Organisation – DIMITRA, the project team has now designed, constructed, and operated the mobile unit for hybrid energy storage unit at the Agios Dimitrios Power Plant. This innovative system represent a significant step toward carbon-neutral energy systems, harnessing CO_2 from flue gases and utilizing renewable hydrogen produced from water electrolysis, to produce biomethane (CH_4)—a clean, non-fossil fuel. Designed to operate in remote and non-interconnected energy systems, the unit brings together advanced technology and sustainable thinking. The successful deployment of this complex, integrated technology was made possible through the collaboration of all project partners.

THREE INTEGRATED SUBSYSTEMS, ONE SMART SOLUTION

The mobile unit for hybrid energy storage *(Figure 1)* consists of three interconnected subsystems:

1. **PEM Electrolyser** to produce renewable hydrogen with a purity of 99%, operating with high water and energy efficiency.

2. **Flue Gas Cleaning Unit**, utilizes a two-stage hollow fiber polyimide membrane to achieving over 90% CO_2 separation efficiency, optimized with parallel compressors and PLC-based control.

3. **Methanation System**, consisting of two parallel trickling bed reactors, adapted from the successful prototype unit, enabling continuous biological conversion of CO_2 and H_2 into methane, with automated gas flow and nutrient circulation systems enabling continuous biological conversion of CO_2 and H_2 into methane, with automated gas flow and nutrient circulation systems.

PROJECT BENEFICIARIES

PPC Renewables

ARISTOTLE UNIVERSITY OF THESSALONIKI

ELGO - DIMITRA
HELLENIC AGRICULTURAL ORGANIZATION - DIMITRA

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CO2 to CH4 Life

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Figure 1. The mobile unit for hybrid energy storage was installed in Agios Dimitrios Plant, next to the desulfurization unit of the plant's fifth chimney.

SAFETY AND AUTOMATION AT THE CORE

The system was built with rigorous safety protocols for H_2 and CH_4 management:

- Routine gas leak monitoring, deployment of flammable gas detectors, and establishment of ignition prohibition zones.
- 24/7 camera surveillance and remote monitoring through the PLC system, ensuring safe, efficient, and low-maintenance operation *(Figure 2)*.

Figure 2. Programmable Logic Controller (PLC) system used to monitor and control the biological methanation reactors. The left panel shows the system's initial interface, while the right displays the configuration and control menu.

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OPERATIONAL HIGHLIGHTS

Over a five-month operational period, the mobile unit demonstrated outstanding performance:

- Achieving **biomethane production with over 95% CH_4 content**, under Gas Retention Time (GRT) of 1 hour, **producing approximately 0.96 m³ biomethane per day** *(Figure 3)*.
- Captured and converted more than **134 kg of CO_2** into biomethane.
- Maintained **low levels of intermediate fermentation metabolites** (Volatile Fatty Acids) at below 0.25 g/L *(Figure 4)* indicating stable and efficient reactor operation.
- Demonstrated **reliable and scalable performance**, supporting the case for larger-scale carbon capture and renewable energy storage applications.

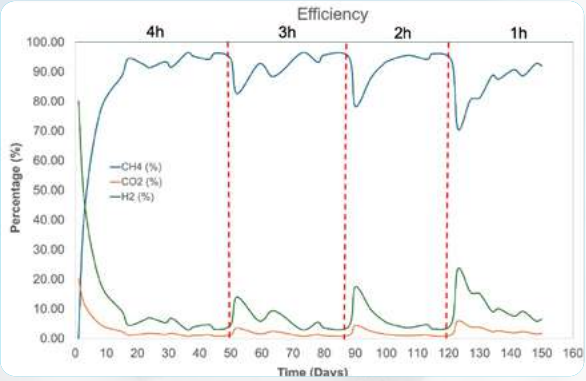

Figure 3. Output gas composition from the mobile unit across various Gas Retention Time (GRT) operation phases, illustrating the system's stable operation.

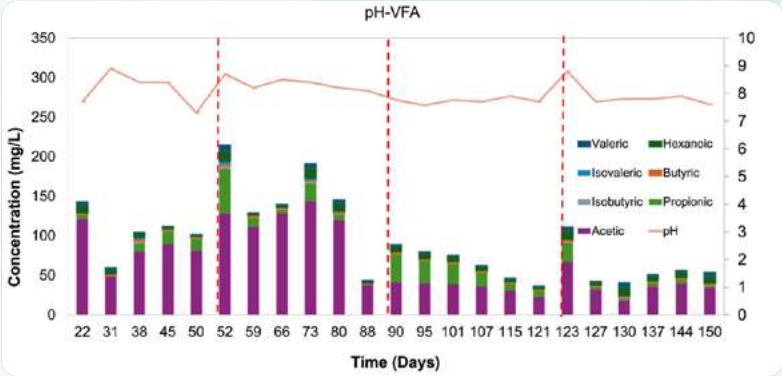

Figure 4. Stacked bar chart showing individual concentrations of Volatile Fatty Acids (VFAs) in mg/L. The red line indicates corresponding pH values throughout the operation.

LOOKING AHEAD

This achievement not only validates the LIFE CO2toCH4 concept but also represents a crucial advancement in utilizing CO_2 for renewable energy production contributing to the EU's broader goals of climate neutrality and energy autonomy. The next phase of the project will see the mobile unit transported to the Technological Park of Lavrion, for further demonstration and validation activities.

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LIVING LABS

LOCATION: AGIOS DIMITRIOS V, PPC POWER PLANT

LIVING LAB MARCH 2025

On February 25, 2025, researchers and stakeholders from LIFE GREENH2ORN convened at the Agios Dimitrios PPC Power Plant for a Living Lab demonstration, where they observed the operational performance of the mobile CO_2 methanation unit and the latest advancements from the LIFE CO2toCH4 project.

This initiative validates the feasibility of CO_2-to-methane conversion using hydrogen, electrolyzers, and biomethanation technology, presenting a scalable pathway toward carbon-neutral energy systems. The CO2toCH4 Living Lab served as a platform to accelerate technological innovation and market deployment, fostered multi-stakeholder collaboration and enhanced public engagement in climate change mitigation. By demonstrating real-world applications of carbon capture and utilization (CCU), we are advancing the transition toward green sustainable technologies.

A sincere thank you to all participants contributing to the evolution of sustainable energy solutions!

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LIVING LABS

LOCATION: AGIOS DIMITRIOS V, PPC POWER PLANT

FINAL LIVING LAB DEMONSTRATION AT THE PPC POWER PLANT IN AGIOS DIMITRIOS MAY 2025

On May 9, 2025, stakeholders from the Municipal Water Supply and Sewerage Company of Kozani and the Region of Western Macedonia gathered at the PPC Power Plant in Agios Dimitrios for the final Living Lab demonstration of the LIFE CO2toCH4 project. During the event, attendees observed the operational performance of the mobile CO_2 methanation unit and explored the latest project advancements in sustainable energy technologies. A heartfelt thank you to all participants for their invaluable contribution!

LOCATION: ELGO DIMITRA

TURNING CO_2 INTO ENERGY: DEPUTY MINISTER VISITS ELGO-DIMITRA'S LIFE CO2toCH4 LIVING LAB SEPTEMBER 2025

On Friday, September 5, 2025, the Deputy Minister of Rural Development and Food, Mr. Ioannis Andrianos, along with the General Secretariat of Agricultural Policy and International Relations, Mr. Antonios Filippis visited the ELGO-DIMITRA premises at the Thermi campus. The visit included a tour of the Living Lab of the LIFE CO2toCH4 project and the pilot biomethanation unit, where cutting-edge research is conducted on the biological conversion of captured carbon dioxide into renewable methane.

During his visit, the Deputy Minister expressed strong interest in the project's potential to provide practical solutions for reducing greenhouse gas emissions. He focused on the possibilities of capturing CO_2 directly from major emitters, such as power plants, and raised questions about the prospects of

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LIVING LABS

transferring this innovative technology to other industrial sectors with significant carbon footprints. He emphasized that such innovations can support environmental protection and the circular economy, while also contributing to energy independence and climate resilience.

The General Secretariat, Mr. Filippis, was equally impressed by the work taking place at ELGO-DIMITRA under the LIFE CO2toCH4 project, noting its strategic importance for Greece's green transition agenda. He highlighted the value of fostering synergies between research institutions, industry, and policy, ensuring that scientific innovation is effectively translated into real-world applications that benefit both agriculture and society at large.

LOCATION: ELGO DIMITRA

LIFE CO2TOCH4 LIVING LAB AT ELGO DIMITRA | THESSALONIKI NOVEMBER 2025

On November 24, 2025, the LIFE CO2toCH4 project welcomed students from the International Hellenic University at the premises of ELGO DIMITRA in Thessaloniki, bringing biomethanation technology closer to real users and the professionals of tomorrow.

During the visit, a prototype pilot unit was presented, demonstrating how CO_2 and H_2 can be biologically converted into renewable methane (CH_4). The unit showcased the project's vision for decentralized, modular and scalable low-carbon energy solutions.

40 students had the opportunity to explore the unit hands-on, gain insight into the microbial processes behind biomethanation, and understand its role in the energy transition towards low-emission energy systems.

By connecting research, education and real-world applications, the LIFE CO2toCH4 project contributes to accelerating innovation and driving the transition to a more sustainable energy future.

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LIVING LABS

LOCATION: LAVRIO

THE 1ST LIFECO2TOCH4 LIVING LAB AT LTCP IS A FACT! DECEMBER 2025

The first LIFE CO2toCH4 Living Lab successfully took place on 18 December 2025 at the Lavrio Technological Cultural Park, marking the official opening of the Living Labs to the public within the LIFE CO2toCH4 (LIFE20 CCM/GR/001642) project.

The event brought together citizens, researchers, students, and stakeholders who had the opportunity to explore how CO_2 can be transformed into renewable biomethane through innovative biomethanation technologies.

The Living Lab opened with a warm welcome by Dr. Konstantinos Moustakas, who introduced the installation and significance of the CO2toCH4 system at Lavrio. This was followed by an insightful presentation from Mr. Vasileios Protonotarios, who highlighted the area's rich mining history - from ancient Greek times (before 3000 BC) to the 20th century - and explained how the park now serves as a hub for cutting - edge green technologies.

Dr. Sofia Mai presented the broader innovation ecosystem of the park, showcasing complementary systems implemented under the LIFE CIRCforBIO (LIFE18 CCM/GR/001180) and CRONUS Horizon Europe (Grant Agreement No. 101084405) projects. The keynote presentation by Maria Kasidoni provided a comprehensive overview of the LIFE CO2toCH4 project, its objectives, technological approach, and expected impact on sustainable energy production.

Participants also took part in guided tours of the park's facilities exploring the transition from historical industrial infrastructure to modern innovation spaces and visited the CO2toCH4 biomethanation and biorefinery units, where the system's design, operation, and environmental benefits were explained in detail.

Overall, the first Living Lab set a strong foundation for the upcoming events, fostering dialogue, knowledge exchange, and public engagement around CO_2 utilization and biomethane production. The active participation and positive feedback confirmed the value of Living Labs as a platform for shaping future clean energy solutions.

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MEETINGS & EVENTS

FINAL INTERNATIONAL DISSEMINATION EVENT IN CYPRUS JUNE 2025

LIFE CO2toCH4 Final International Dissemination Event took place on Wednesday, 25th June, within the 12th International Conference on Sustainable Waste Management. Participants were presented with the project's technological innovations by the project partners' representatives: Dr. Sabina Psaltou from PPCR, Dr. Kougias from ELGO, Prof. Stef. Campanaro from UNIPD, PhD candidate A. Chatzis from AUTH, and H. Partheniou & S. Konstantinidi from PPCR. The session was chaired by the project coordinator, Dr. A. Antoniadis from PPCR, M. Georgiadou from the EC Directorate-General for Research and Innovation, and Dr. Kougias from ELGO. An insightful discussion followed the presentations, with the participation of conference attendees, including Eva Nanaki from Hellenic Energy.

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MEETINGS & EVENTS

LIFE CO2TOCH4 AT FORWARD GREEN EXPO 2025 MARCH 2025

From March 13-15, 2025, the LIFE CO2toCH4 project participated in the Forward Green Expo in Thessaloniki, a leading event dedicated to sustainability and green development. During the event, we had the opportunity to present key project results, engage with stakeholders, industry experts, and policymakers, and exchange insights on the role of CO_2 conversion technologies in fostering a more sustainable and circular energy system. A key highlight was our presentation on March 15 on the open stage, where participants learned about the LIFE CO2toCH4 project's impact and role in advancing green energy solutions.

We sincerely appreciate everyone who visited our booth, engaged in discussions, and contributed to the success of this event!!

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MEETINGS & EVENTS

PIONEERING THE FUTURE OF CLEAN ENERGY: GREEN HYDROGEN & BIOMETHANE WORKSHOP IN KOZANI MARCH 2025

On February 25, 2025, the LIFE GREENH2ORN and LIFE CO2toCH4 projects hosted an insightful workshop in Kozani, bringing together experts, policymakers, and industry leaders to explore the potential of green hydrogen and biomethane in shaping a cleaner energy future.

The event united key stakeholders from local government, research institutes, and industry, including the Region of Western Macedonia, Municipality of Kozani, PPC Renewables, CluBE-Cluster of Bioeconomy and Environment of Western Macedonia, Soil & Water Resources Institute, ELGO-DIMITRA, B&T Composites, and DIADYMA SA, to share valuable insights on the critical role these technologies play in building a more sustainable energy system.

Exciting steps ahead in turning these technologies into real-world solutions! Let's continue to innovate and drive sustainable energy transformation together.

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MEETINGS & EVENTS

ADVANCING SUSTAINABLE ENERGY: LIFE GREENH2ORN & LIFE CO2TOCH4 COLLABORATIVE WORKSHOP IN KOZANI MARCH 2025

On February 25, 2025, in Kozani, the LIFE GREENH2ORN and LIFE CO2toCH4 projects joined forces for a collaborative workshop, driving innovation in alternative fuels to reduce CO_2 emissions and promote a more sustainable and resilient energy future.

Key stakeholders from the Region of Western Macedonia, the Municipality of Kozani, PPC Renewables, CluBE-Cluster of Bioeconomy and Environment of Western Macedonia, Soil & Water Resources Institute, ELGO-DIMITRA, B&T Composites, and DIADYMA SA, came together to explore the potential of green hydrogen and biomethane for a sustainable energy future.

Mr. Nikolaos Ntavos (CluBE) presented the LIFE GREENH2ORN Project, while Dr. Apostolos Antoniadis (PPCR) shared the major results of the LIFE CO2toCH4 project. Dr. Panagiotis Kougias (ELGO DIMITRA) highlighted the role of hydrogen in

the biological upgrading of biogas, and Dr. Georgios Varvoutis (CluBE) provided an overview of Power-to-X schemes. Mr. Vassilios Tiriakidis (B&T Composites) discussed hydrogen storage technologies, and Dr. Marinela Zhurka (DIADYMA) explored the circular management of sewage sludge for sustainable hydrogen production. We were also honored by the presence of Vice-Regional Governor Mr. Lyssandros Metaxas, who reinforced the region's commitment to sustainability.

This workshop was a great opportunity to exchange knowledge, foster collaboration, and shape a resilient, low-carbon future for Western Macedonia. The discussions emphasized the transformative potential of hydrogen and biomethane in achieving energy transition goals.

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MEETINGS & EVENTS

LIFE CO2TOCH4 AT VERDE.TEC 2025: ADVANCING CO_2 CAPTURE AND RENEWABLE ENERGY STORAGE FEBRUARY 2025

On February 21, 2025, at Verde.tec 2025 in M.E.C. Paiania, the LIFE CO2toCH4 project was showcased as a groundbreaking solution for CO_2 capture, utilization (CCU), and renewable energy storage. Experts and industry leaders gathered to explore this innovative, integrated industrial process, which aims to transform CO_2 emissions into a valuable non-fossil biofuel—methane.

The project's key highlight is the development of a smart mobile unit (TRL8) capable of hybrid energy storage, designed for remote areas and islands that are not connected to the central energy grid. The technology leverages renewable energy sources (RES) for water electrolysis, producing hydrogen (H_2), which is then biologically converted into methane using CO_2 from exhaust gases.

By combining CO_2 reduction with renewable energy storage, LIFE CO2toCH4 presents a game-changing solution for decarbonization and sustainable energy transition. The discussions at Verde.tec reinforced the urgent need for scalable, innovative energy solutions that contribute to climate neutrality and a greener future.

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MEETINGS & EVENTS

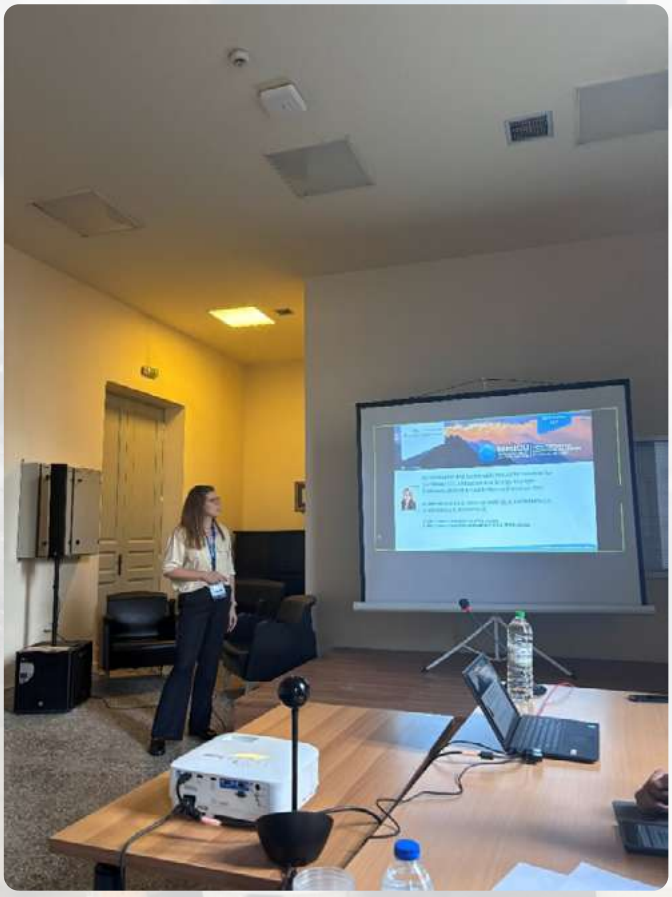
LIFE CO2TOCH4 AT THE MEDITERRANEAN GEOSCIENCES UNION (MEDGU 2025) NOVEMBER 2025

The LIFE CO2toCH4 project was proudly featured at the Mediterranean Geosciences Union (MedGU 2025) Conference in Athens, with representatives from Public Power Corporation Renewables S.M.S.A. (PPCR) and Public Power Corporation S.A. (PPC) participating on behalf of the project.

Our presentation, entitled "An Innovative and Sustainable Industrial Solution for Combined CO_2 Utilization and Energy Storage: Demonstration of a Mobile Bio-methanation Unit," showcased the project's pilot-scale implementation together with a focused techno-economic assessment (TEA) analysing LCOE, OPEX and key cost drivers — offering clear insights into the scalability and competitiveness of CCU-based biomethane.

An extended abstract with the same title was also submitted and accepted for publication in the conference proceedings.

Our participation in MedGU 2025 further strengthens the project's contribution to scalable, sustainable and EU-aligned low-carbon solutions for the energy transition.



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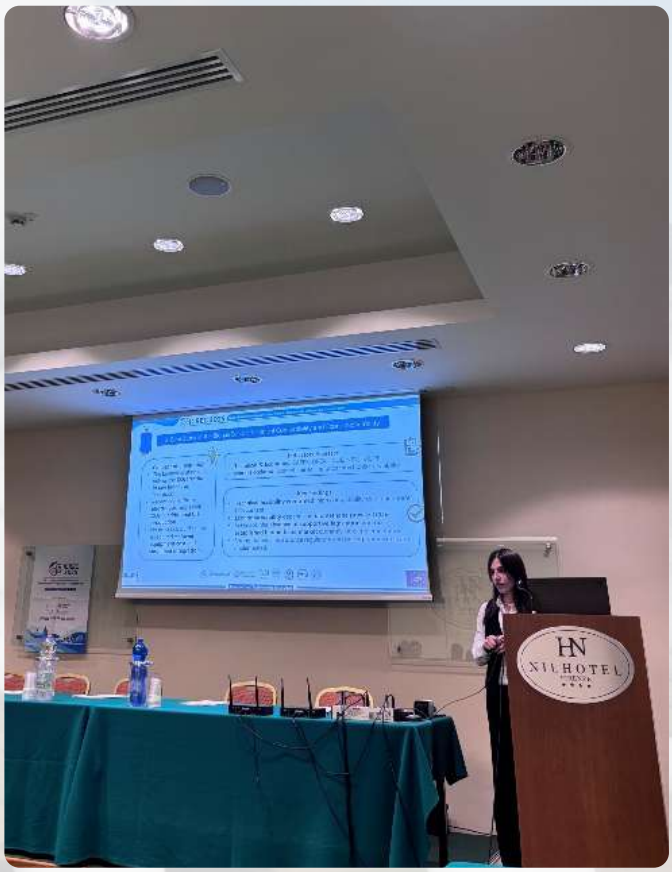
MEETINGS & EVENTS

THE LIFE CO2TOCH4 PROJECT PARTICIPATED IN THE 10TH INTERNATIONAL CONFERENCE ON RENEWABLE ENERGY AND CONSERVATION (ICREC 2025) NOVEMBER 2025

The LIFE CO2toCH4 project participated in the 10th International Conference on Renewable Energy and Conservation (ICREC 2025) in Florence (21–22 November 2025), with representatives from the Public Power Corporation (PPC) and Public Power Corporation Renewables (PPCR) teams. The project contributed both an extended abstract and an oral presentation during Oral Session 4: "Renewable Energy in Action: Building Sustainable Communities."

The study, titled "A Methodological Approach for the Techno-Economic Assessment of CO2toCH4 Technology: Insights from the LIFE CO2toCH4 Project," was prepared through the collaboration of the PPC–PPCR teams (A. Antoniadis, E.I. Partheniou, S. Konstantinidi, A. Servou, C. Roumpos).

The work presents the project's comprehensive approach to evaluating the techno-economic feasibility, scalability and transferability of CO2toCH4 technology, demonstrating its potential applications across the energy, biogas and cement sectors and its contribution to sustainable energy innovation.



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PUBLICATIONS

SCIENTIFIC PUBLICATIONS: LIFE CO2TOCH4 PROJECT DRIVING SUSTAINABLE INNOVATION MARCH 2025

Scientific achievements from the LIFE CO2toCH4 project! Our research advances sustainable waste management and biological methanation, published in leading journals.

1. KEMET – A python tool for KEGG Module evaluation and microbial genome annotation expansion *(https://www.sciencedirect.com/science/article/pii/S2001037022000903)*

2. Integrating metagenomic binning with flux balance analysis to unravel syntrophies in anaerobic CO_2 methanation *(https://pubmed.ncbi.nlm.nih.gov/35918706/)*

3. Strain-resolved metagenomics approaches applied to biogas upgrading *(https://doi.org/10.1016/j.envres.2023.117414)*

4. Comparative study on packing materials for improved biological methanation in trickle Bed reactors *(https://doi.org/10.1016/j.biortech.2023.129456)*

5. Membrane-based technologies for post combustion CO_2 capture from flue gases; recent progress in the employed membrane materials *(https://ikee.lib.auth.gr/record/356505/files/Zouboulis%20et%20al.pdf)*

6. Impact of trace metal supplementation on anaerobic biological methanation under hydrogen and carbon dioxide starvation *(https://doi.org/10.1038/s41522-025-00649-2)*

7. Core cooperative metabolism in low-complexity CO_2-fixing anaerobic microbiota *(https://doi.org/10.1093/ismejo/wraf017)*

8. pan-Draft: automated reconstruction of species-representative metabolic models from multiple genomes *(https://doi.org/10.1186/s13059-024-03425-1)*

9. Sustainable Food Waste Management in Anaerobic Digesters: Prediction of the Organic Load Impact by Metagenome-Scale Metabolic Modeling *(https://doi.org/10.1021/acs.est.4c11180)*

10. Modelling microbial and metabolic shifts in trickle bed reactor biomethanation at decreasing gas retention times *(https://doi.org/10.1016/j.cej.2025.167574)*

11. Harnessing the Influence of Pressure and Nutrients on Biological CO_2 Methanation Using Response Surface Methodology and Artificial Neural Network—Genetic Algorithm Approaches *(https://doi.org/10.3390/fermentation11010043)*

12. Biological methanation (BM): A state-of-the-art review on recent research advancements and practical implementation in full-scale BM units *(https://doi.org/10.1016/j.enconman.2024.118733)*

13. Comparative study on packing materials for improved biological methanation in trickle Bed reactors *(https://doi.org/10.1016/j.biortech.2023.129456)*

14. Assessment of the performance of packing materials in trickle bed reactors for efficient biomethanation *(https://doi.org/10.1016/j.jece.2025.119480)*

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CO2toCH4 BENEFICIARIES

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CO2 to CH4 Life

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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 June 2026, in selected regions of Greece and Italy.

CO2toCH4 STAY CONNECTED!!

WEBSITE

> For more news & updates please visit our website:
https://co2toch4.eu/

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