



Co-funded by
the European Union



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CO₂ to CH₄ *Life*

Layman's report

Demonstration of a mobile unit
for hybrid energy storage based on CO₂
capture and renewable energy sources



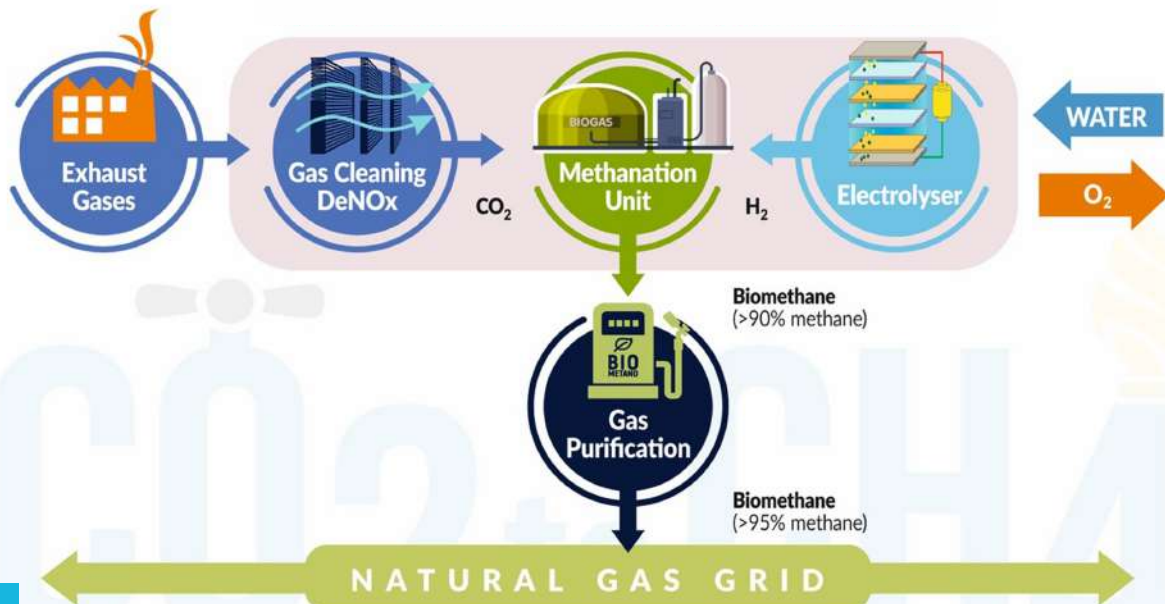
Project Overview

LIFE CO₂toCH₄ is a European Union–co funded project that develops and demonstrates an innovative way to store renewable energy while reducing carbon dioxide (CO₂) emissions. The project focuses on capturing CO₂ from industrial exhaust gases and combining it with hydrogen (H₂) produced from renewable electricity to create biomethane (CH₄), a renewable, non fossil fuel.

The core outcome of the project is the construction, testing, and operation (Technology Readiness Level 8) of a **smart, mobile hybrid energy storage unit**. This unit is designed to operate in **remote or low capacity energy systems**, such as islands or isolated areas that are not connected to a central electricity grid.

The innovative technology uses the excess renewable electricity to split water and produce hydrogen. The hydrogen is then combined with carbon dioxide from exhaust gases and converted through a biological process into methane, which a renewable, non-fossil fuel.

By converting excess renewable electricity into a stable fuel, LIFE CO₂toCH₄ addresses both energy storage challenges and climate change mitigation.



Project Objectives

THE OBJECTIVES

01



Efficient energy storage and CO₂ capture & utilisation

By constructing, testing and operating (TRL8) a smart mobile unit for hybrid energy storage able to be installed in remote energy systems that commonly have low capacity.

02



Maximise efficiency

By developing technically advanced systems and control architectures based on microbial resource management.

03



Process Sustainability

By demonstrating system evaluation and assessment of environmental, economic and social impacts.

04



Market exploitation

By identifying any safety, environmental, regulatory, or resource (economic) constraints that may affect its penetration into the market./ By assessing the viability, cost and benefits of the proposed system.

05



Replication, Transferability

By defining business requirements and critical success factors that must be met.

06



Promote public awareness on climate change mitigation & circular economy concepts.

By fostering employment growth and increasing capacity building in relevant technologies for increased competitiveness. / By contributing to the implementation of the EU policy and legislation.

The Problem Addressed

Europe's transition to renewable energy faces **three** major challenges:

- Renewable energy sources (such as wind and solar) produce electricity intermittently, leading to surplus energy that is difficult and expensive to store.
- Energy intensive industries and power plants continue to emit large quantities of CO₂.
- Remote regions and islands are particularly vulnerable, as they face higher risks of power outages and often rely on fossil fuels for energy security.

LIFE CO₂toCH₄ tackles these challenges by transforming CO₂ from a waste product into a valuable energy carrier, while enabling long term storage of renewable electricity.



The LIFE CO₂toCH₄ Mobile Unit for Hybrid Energy Storage



The CO₂toCH₄ Solution

The LIFE CO₂toCH₄ system integrates several technologies in one smart mobile unit:



Producing Green Hydrogen:

Renewable electricity is used to split water through electrolysis, producing green hydrogen.



Capturing carbon dioxide:

CO₂ is captured from exhaust gases using advanced separation methods, including membrane based systems.



Turning gases into renewable fuel:

With the help of naturally occurring microorganisms, H₂ reacts with the

captured CO₂ and is converted into biomethane, which is a renewable, non-fossil fuel.



Storing and using the fuel:

Biomethane is stored and can later be used as a renewable fuel or injected into existing gas infrastructure.

This solution makes it possible to store renewable energy in a **stable and transportable form**. At the same time, it significantly reduces greenhouse gas emissions by reusing the CO₂ instead of releasing it into the atmosphere.





Technical Progress and Innovation



The LIFE CO₂toCH₄ project has successfully designed, optimized and operates a pilot scale methanation unit, that brings together several key components:

- An electrolyzer for green hydrogen production
- Equipment to clean, and supply CO₂ from exhaust gases
- Two ex situ biological methanation reactors

Significant effort has been dedicated to **microbial resource management**. Research teams carefully developed and optimized hydrogen consuming microbial communities, ensuring stable and efficient methane production even when using impure CO₂ streams. To better understand and support these living systems, our team used advanced monitoring methods to study how the microbial communities behave and how to keep them healthy and productive.

These developments ensure high efficiency, robustness, and safety of the overall system.

Climate and Environmental Benefits

LIFE CO₂toCH₄ delivers strong environmental benefits:

- **Substantial reduction of CO₂ emissions** by capturing and reusing carbon instead of releasing it into the atmosphere
- **Decarbonisation of energy intensive industries** through the use of renewable fuels
- **Efficient use of renewable electricity**, avoiding curtailment and grid instability

- Contribution to the **EU climate neutrality target by 2050**

By transforming CO₂ from a waste gas into a useful resource, the project supports a circular carbon economy, where emissions are reused instead of discarded. This approach helps reduce greenhouse gases and supports global efforts to limit temperature rise under international climate agreements.

Economic and Social Impact

The project evaluates beyond technical performance to understand whether the solution is economically and socially viable. LIFE CO₂toCH₄ project:



Offers affordable energy storage for remote areas, where communities that are far from main energy grids can store renewable energy in fuel form and use it when needed.



Creates new business opportunities by supporting emerging markets that capture CO₂ and turn it into useful products instead of treating it as waste.



Improves **energy security** by reducing dependence on fossil fuel imports



Promotes **job creation and skills development** in advanced clean energy technologies

Because the system is built as a **mobile unit**, it can be transported and installed in different locations, including industrial sites and remote regions. This flexibility makes it easier to adapt the solution to local energy needs.

Policy Relevance of Biomethane in the Evolving EU Framework

Biomethane is becoming increasingly prominent within the EU's recently updated climate and energy framework. With the adoption of the Fit-for-55 package from 2021 onwards, key legislation across transport, energy, buildings, and industry has been revised to raise climate ambition and accelerate decarbonisation. Within this evolving framework, renewable gases—particularly biomethane—are gaining strategic importance.

Although not legally binding, the REPowerEU Plan has reinforced this direction by linking renewable gas deployment with energy security considerations and by setting a dedicated biomethane production objective. At the same time, sustainability provisions under RED II and RED III introduce stricter greenhouse gas reduction thresholds and limit the contribution of crop-based biofuels, thereby steering development toward advanced and waste-based biomethane pathways.

Other recently strengthened EU legislation also influences biomethane's role. The Waste Framework Directive and the Common

Agricultural Policy affect feedstock availability and sustainability conditions, while the Landfill Directive increases incentives to recover organic waste streams. Carbon pricing under the EU Emissions Trading System (ETS) enhances the relative competitiveness of low-carbon fuels, and the EU Taxonomy channels private investment toward activities aligned with climate objectives.

Together, these measures are reshaping the incentive landscape for biomethane. While earlier market development relied heavily on direct public support mechanisms such as feed-in tariffs and capital subsidies, the current policy direction signals a gradual transition toward market-based drivers. Competitive tenders, contracts for difference, renewable fuel mandates, greenhouse gas intensity targets, and carbon pricing are increasingly expected to stimulate both production and demand. This reflects a broader policy shift toward integrating biomethane into energy and carbon markets rather than supporting it primarily through administratively determined subsidies.

As this legislative framework is still being implemented and operationalised, coordination across energy, agriculture, waste, and climate policy will be critical. The coming years will determine how effectively

these recently adopted instruments translate into investment signals, sustainable feedstock mobilisation, and measurable emissions reductions.

Replicability and Transferability

The CO₂toCH₄ concept is designed to be **flexible, scalable and easy to apply in many different settings.**

It can be transferred and adapted as:

- **It suits multiple industrial sectors**
The system can work with CO₂ emissions from sectors such as cement & food industry, steel manufacturing, oil refineries, waste-to-energy plants, and biogas facilities. These sectors often produce concentrated CO₂ streams that can be captured and reused.
- **It can handle impure CO₂ streams**
The technology has been tested with CO₂ that contains small amounts of other gases. This makes it more practical for real industrial conditions, where CO₂ is rarely perfectly pure.

- **It fits into existing infrastructure**
The produced biomethane can be stored, transported, or injected into current gas networks. The system can also be connected to renewable electricity sources already in place, such as wind or solar farms.

Its modular and mobile components allow for its deployment in different regions, ranging from industrial clusters to remote energy systems. This makes the technology suitable for broad use across Europe and potentially worldwide, supporting both industrial decarbonisation and renewable energy storage.

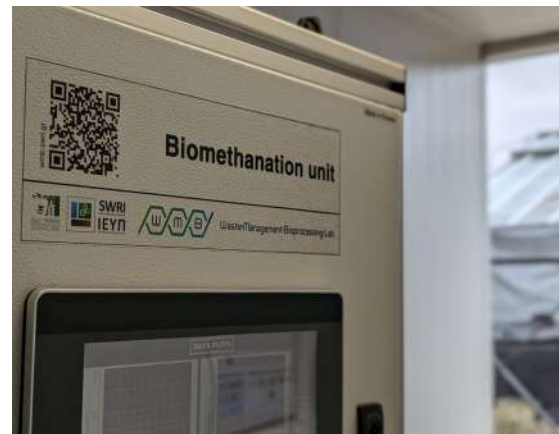
Technoeconomic feasibility study findings

The techno-economic feasibility study undertaken during the project implementation examined technical and economic viability of implementing the proposed technology under several power plant capacities and different industry sectors. The findings emphasize the critical influence of the investment costs, energy consumption and biomethane pricing in determining the system's economic feasibility, consistent with conclusions from the reviewed literature. The techno-economic

indicators of the LIFE CO₂toCH₄ technology depends on CAPEX, OPEX and legislative framework of the energy market.

This study underscores the potential of biomethanation as a sustainable energy solution, particularly when paired with renewable energy sources and effective carbon utilization strategies. Moving forward, further research into cost-reduction measures and supportive policy frameworks is required.





Communication and Dissemination Activities Outreach & Impact

The project actively promotes public awareness of climate change mitigation, circular economy principles, and clean energy technologies having reached an estimated over 10559 stakeholders. Communication and Dissemination activities were addressed to a wide range of stakeholders including the Academic & Research Community, Technology Providers, End Users, Policy Makers, Public Authorities including Ministries, Regional & Municipal Authorities and the General Public through a wide range of undertaken activities:

- A dedicated project website and social media presence
- Noticeboards placed in both the beneficiaries' premises and the sites hosting the LIFE CO₂toCH₄ prototype unit
- Roll up banners, leaflets, press articles

- Organisation of Living Labs
- Participation in international conferences and exhibitions
- Public events and stakeholder meetings

A 3D virtual tour of the pilot installation allows the public and stakeholders to explore the technology and its components and may be found at the project website:



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Project Impact

Overall, LIFE CO₂toCH₄ has a long-lasting impact by showing a practical, near market-ready solution for decarbonisation that can be replicated across Europe to accelerate the journey toward climate neutrality. The project demonstrates that turning CO₂ into renewable fuel is not just an idea for the future, but a realistic option that can be applied in many regions. By proving the technology

works under real conditions, LIFE CO₂toCH₄ helps move carbon valorisation beyond demonstration and become a cornerstone of Europe’s sustainable energy future. Building on these achievements, LIFE CO₂toCH₄ paves the way for large-scale deployment of CO₂-to-biomethane solutions, helping transform Europe’s climate goals into real, on-the-ground action.





After-LIFE Plan

The After-LIFE Plan will carry the project's results into the future, ensuring they continue to create value and make a difference. Partners will develop new projects and proposals, supported by European or national programs, to expand the reach of the innovations and bring their benefits to more communities. At the same time, the team will follow new technologies and changes in energy regulations, so the results

remain relevant and can be applied in future initiatives when conditions are right. The project website and communication channels will stay active, sharing updates, lessons learned, and creating connections with other EU projects and initiatives. Through these actions, the LIFE CO₂toCH₄ unit and other project achievements will continue to inspire, grow, and contribute to sustainable solutions for people and the environment



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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.

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WEBSITE

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

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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.



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