Anaerobic digestion, CO_2 management and future technologies

Biogas and **biomethane** are becoming increasingly important as renewable alternatives and a lot of efforts in terms of implementation of supportive policies and market incentives is was carried out.

Overview of future potential developments

- Integration with renewable energy systems → Hybrid energy system (wind, solar...)
- Hydrogen integration → New opportunities for renewable H_2 production
- Decentralisation and localised energy production → Smaller-scale biogas plants closer to the source of feedstocks

Feedstock diversification

Biogas and biomethane production mostly relies on agricultural waste and animal manure, meaning 65% of EU resources. Advancements in technologies have enabled the use of a broader range of feedstocks.

> “ Circular economy ”

This is crucial for promoting circular economy and expanding biomass availability through access to diverse feedstocks.

Types of anaerobic digesters and monitoring

- Passive Systems: Biogas recovery integrated into existing treatment components.
- Low-Rate Systems: Manure-fed digesters, primarily relying on naturally occurring methane-forming microorganisms.
- High-Rate Systems: Digesters with trapped methane-forming microorganisms, enhancing efficiency.

Effective **monitoring** is essential for optimizing plant performance and reducing analytical costs, ensuring consistent process control. Real-time, in-line monitoring provides continuous insights into the digester's behavior.

> “ In-line monitoring enables a real time overview ”

Incorporating small quantities of inorganic components, specifically carbon-encapsulated iron nanoparticles (OPS), into the digestion process can enhance bacterial activity and thereby increase biogas yield.

CO_2 management

As mentioned in the previous factsheet “What is biomethane and how it is used”, once the biogas has formed, it consists of a blend of different gases, including CO_2, which can be captured and used in ther sectors, for example by creating local synergies with CO_2-consuming industries.

Different ways of capturing CO_2 from AD

- Captured in the flue gas during biogas combustion;
- Through the production of biohydrogen;
- Gasification of sustainable biomass.

Theoretical potential of biogenic CO_2 from biogas

	Biogas and biomethane production In Europe	Theoretical potential of biogenic CO_2 from biogas	Equivalence
2020	18 bcm	24 Mton	Equivalent of the GHG emissions of Croatia in 2020
2030	35 bcm	46 Mton	Equivalent of the GHG emissions of Sweden in 2020
2050	95 bcm	124 Mton	3% of EU-27 GHG emissions in 2020

Estimates assuming that all biogas is upgraded to biomethane and that all resulting biogenic CO_2 is stored permanently.

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What are the advantages of using CO_2 from biogas?

Politics

- Synergies in a local bioeconomy system

Marketing

- Image impact;
- biogenic status vs fossils

Economics

- Locally produced;
- Price stability;
- Programmable production;
- Securedsupply &/or exclusivity conditions

Technical

- concentration typically >98%;
- No presence of CO;
- Typically low concentration of NH_3;
- Typically low concentration of H_2S;
- Main contaminants not toxic.

Different pathways for CO_2 use

Given the multiple pathways for CO_2 utilization, they can be broadly categorized into two main groups:

- Direct CO_2 Utilization: employing CO_2 directly as a feedstock without prior conversion;
- Indirect CO_2 Utilization: requiring preliminary CO_2 conversion before its subsequent utilization.

Advances in biomethane technology: integrating anaerobic digestion systems

Biochar production plants

Biochar main characteristics

- It is a versatile substance produced by slow pyrolysis process;
- High surface area;
- Able to improve structure and fertility of soils;
- Ability to sequester carbon in the soil for a long period of time (hundreds / thousands of years).

Coupling with an anaerobic digestion process

By incorporating slow pyrolysis, for example, through biochar production, the traditional composting of solid digestate can be replaced. This not only adds value to the process but also opens up opportunities for carbon removal certification.

SAF production via Fischer-Tropsch syntesis

Fischer-Tropsch syntesis main characteristics

- Converts biomass into liquids;
- Basic steps include syngas;
- Syngas can be obtained via gasification of biomass, or through reforming or partial oxidation of methane;
- By Fischer-Tropsch reaction, we obtain liquid hydrocarbons.

e-methane

CO_2 emissions from biogas production can be repurposed through carbon capture and utilization (CCU). By combining captured CO_2 with renewable hydrogen or electricity, additional biomethane can be produced. This offers a strategic opportunity for regions with high renewable energy penetration to optimize energy systems and mitigate climate change.

Different pathways for e-methane production

Biological methanation

This process leverages the use of microorganisms to convert CO_2 and hydrogen into methane and water. This method operates at lower temperatures compared to traditional catalytic methanation. It is particularly well-suited for smaller-scale plants, as it can efficiently utilize CO_2 as a feedstock.

Catalytic methanation

Use of a metal catalyst to convert a mixture of carbon dioxide and hydrogen (or carbon monoxide and hydrogen) into methane and water. To ensure efficient conversion, impurities like hydrogen sulfide (H_2S) must be removed as they can negatively impact the catalyst's performance.

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Biomethanol

Biomethanol main characteristics

It is a light, colourless and easily flammable and water soluble liquid. It is derived from renewable sources, being a sustainable alternative to fossil fuels.

How methanol is used

Of the total global methanol demand, approximately 60% is utilized by the chemical industry as a key intermediate in the production of a wide range of chemicals. The remaining 40% is consumed in the fuel industry, either as pure methanol or blended with other fuels

Production key-steps

Biomethanol production is a multi-step process that includes syngas generation, methanol synthesis, and subsequent purification. The primary distinction from other production methods is the approach to syngas generation.

Biohydrogen

Biohydrogen main characteristics

The word "biohydrogen" refers to hydrogen obtained from biogenic sources. There are several different technologies to produce it, including biological, thermochemical and bioelectrochemical processes.

Details of biological processes

Dark fermentation

Biomethane production involves microorganisms that generate hydrogen, bio-CO_2, organic acids, and alcohols. This process includes hydrolysis, acidogenesis, and acetogenesis stages, the latter two of which produce hydrogen and CO_2.

Biophotolysis

This process includes all hydrogen produced by photosyntesis, under anaerobic conditions, and it can be direct or indirect depending on the way electrons are used within the process.

Photofermentation

Photofermentation using purple non-sulfur bacteria is also a method for producing biohydrogen. These bacteria utilize organic substrates and light to grow and generate hydrogen.

Gasification

Gasification main characteristics

In this high-temperature process (800-1,200°C), biomass and solid wastes are converted into syngas. By limiting the presence of oxidizing agents (steam or oxygen), complete combustion is prevented. Additional by-products, including biochar and tars, are also generated.

Steam methane reforming

The process involves a high-temperature reaction between methane and steam, catalyzed to produce primarily hydrogen and carbon monoxide. The carbon monoxide is further converted into CO_2, increasing the overall hydrogen yield.

Microbial electrolysis

Biomethane production leverages microbial cells to oxidize organic substances, similar to water electrolysis. However, instead of using electricity, the microbes' electroactive ability drives the oxidation process. The subsequent hydrogen generation step is identical to traditional water electrolysis.

This factsheet refers to an official report produced by the GreenMeUp consortium. To have access to the full document for more detailed information, please click here.

About the project

GreenMeUp is an Horizon Europe Coordination and Support Action started on the 1st of August 2022, that will continue through 31 July 2025. The project is carried out by a Consortium of 14 partners from 10 European Countries. GreenMeUp is coordinated by CRES - Centre for Renewable Energies Sources and Savings (Greece).

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