WP3 TASK 3.3

Industrial applicability of biogenic PtG

ABSTRACT

Task 3.3 investigated the potential of biomethanation in Finland if carbon dioxide (CO_2) from biogas would be converted to methane. There is a potential to increase the methane production at biogas plants in Finland from ca. 130 Mm^3/a (1.3 TWh/a) in 2020 to ca. 540 Mm^3/a (5.4 TWh/a) in 2030, when considering both the new biogas plants and potential use of biomethanation technology. Biomethanation presents ca. 30% of methane produced. Furthermore, the environmental performance of using hydrogen (H_2) in *in-situ* and *ex-situ* biomethanation processes to enhance biogas methane content was evaluated with life cycle assessment and compared to traditional membrane separation technology. Results indicate that upgrading biogas by membrane separation achieves a 59% emission reduction, while ex-situ and in-situ biomethanation achieve reductions between 49% and 62%, depending on the electricity source for H2 production, comparing to the baseline where natural gas is used. Finally, the effects of variations in gaseous feedstock availability and composition on biomethanation process and its efficiency were reviewed. These results indicate that *in-situ* biomethanation is more sensitive to standby periods in the feeding compared to *ex-situ* biomethanation, and that the main impurities in the CO_2-rich feedstocks that may negatively affect biomethanation process include nitrogen and sulfur oxides, hydrogen sulfide, and heavy metals.

MOTIVATION

Biogenic CO_2 is produced, e.g. in pulp and paper industries, ethanol plants and biogas plants. Combining CO_2 with H_2 enables the production of methane via biomethanation that utilizes microorganisms for the conversion process. Biomethanation can be realised 1) via *in-situ* feeding of H_2 to biogas reactor processing organic waste (*in-situ* biomethanation), or 2) in external reactor converting CO_2 and H_2 into methane (*ex-situ* biomethanation). It was in the interest of this task to find out, what is the biomethanation potential in Finland, what are the environmental impacts of the technology, and what is the resilience and adaptability of the technology for the gaseous feeds that may fluctuate in availability and purity.

RESULTS

The biomethanation potential in Finland was evaluated from the perspective of available CO_2 in biogas and bioethanol plants. Information from Finnish Biocycle and Biogas Association on the biogas and methane production in 2020 and 2030 (estimations) and typical Finnish biogas processes and conversion rates were used as basis of the calculations. Compared to 2020, it is expected that biomethane production increases from ca. 130 Mm^3/a to ca. 540 Mm^3/a by 2030 due to building new biogas plants, increased biogas upgrading, and biomethanation of CO_2 in the biogas or after biogas upgrading (Figure 1).

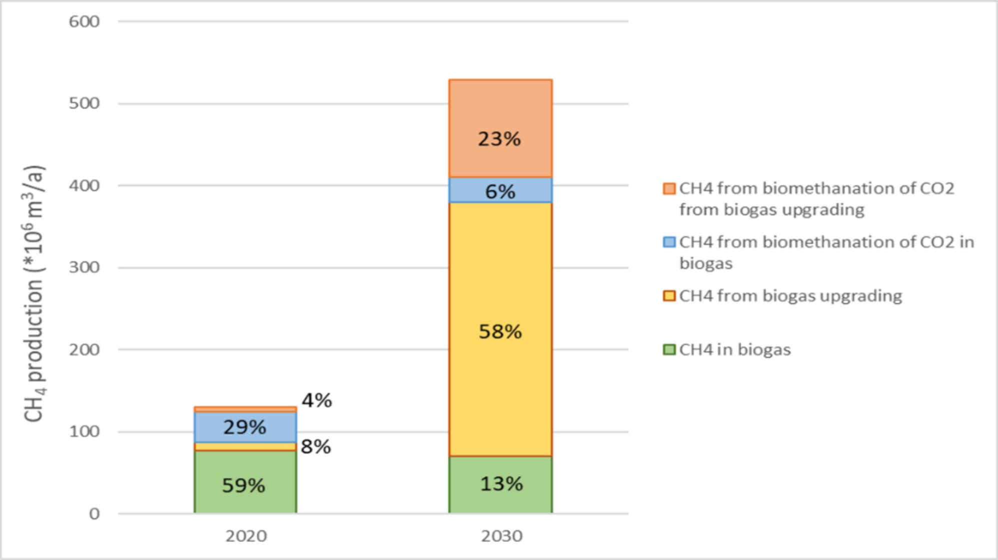

Figure 1. Methane (CH_4) production potential in 2020 and 2030 considering methane present in the biogas produced from organic feedstock in biogas plant, methane that is separated from biogas via biogas upgrading, and production of methane via biomethanation of the CO_2 present in the biogas or separated from biogas via biogas upgrading.

The environmental impacts of utilizing of H_2 either *in-situ* or *ex-situ* biomethanation process to increase the methane content of biogas were evaluated using the LCA method, and the performance was compared with traditional upgrading technologies. This was done in a case study, where a biogas process treated various organic waste streams. This results that different scenarios can significantly reduce emissions when using methane as vehicle fuel, compared to a baseline scenario (S0) (Figure 2). Specifically, membrane separation (S1) of methane form biogas achieves a 59% reduction in emissions compared to the baseline scenario (S0). *Ex-situ* biomethanation (S2) offers emission reductions ranging from 50% to 62%, depending on the electricity source used for hydrogen production. *In-situ* biomethanation (S3) provides emission reductions ranging from 49% to 61%, also depending on the electricity source for hydrogen production. The choice between using a PEM or an alkaline electrolyzer in both ex-situ (S2) and in-situ (S3) biomethanation scenarios results in negligible differences in emission reductions (approximately 0.3%).

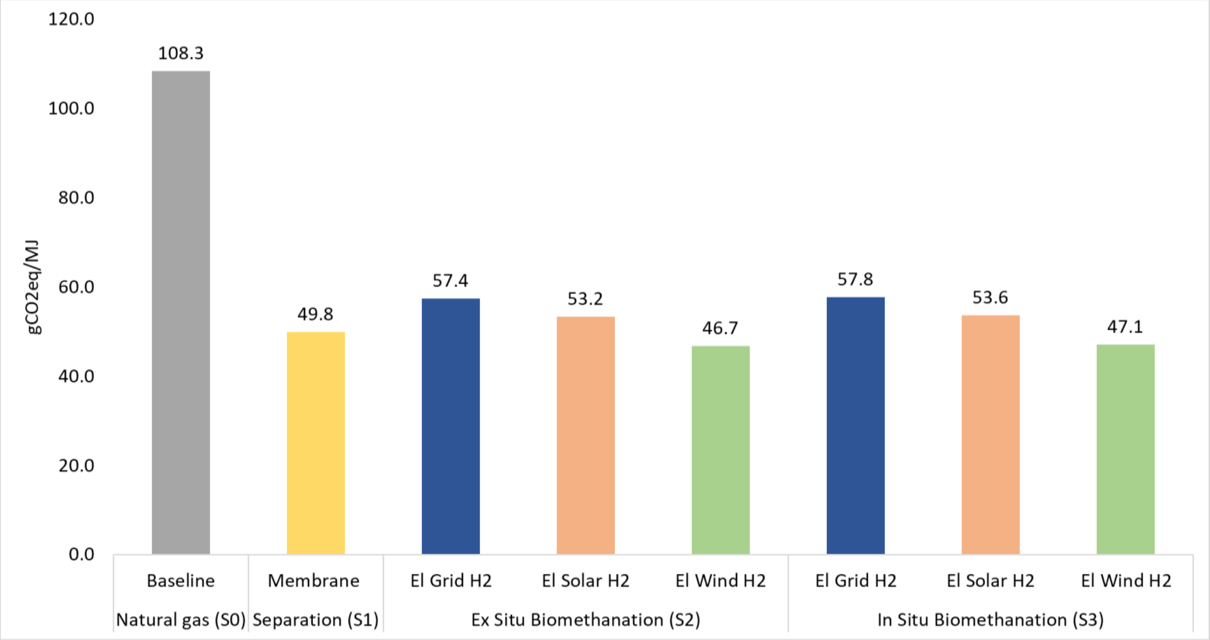

Figure 2. The life cycle impact assessment for the climate change impact category (GWP100) for Natural gas (S0), Membrane separation (S1), Ex-situ biomethanation (S2), and In-situ biomethanation of biogas (S3).

Biogenic CO_2 sources are tied to certain locations. H_2, on the other hand, can be produced at various locations via electrolysis by using renewable electricity, such as wind or solar energy, or via biomass gasification. The different technologies used to produce H_2 affect the purity of the stream. The availability of excess renewable energy varies in time, which may affect the availability of H_2 for the biomethanation process. Usually stable feeding, including gas flow rate and stoichiometric ratio of H_2 and CO_2, is essential for stable operation of a biomethanation process. Although the results on variations in feedstock availability vary based on literature, in general, short standby periods of up to six hours enable quick recovery of the process, while longer standby periods of one day or more require longer recovery time from hours to days. *Ex-situ* biomethanation is more resilient for standby periods than *in-situ* biomethanation.

Furthermore, the biogenic CO_2 sources may contain some impurities negatively affecting the microorganisms in biomethanation process, including nitrogen and sulfur oxides, hydrogen sulfide, heavy metals, and volatile organic compounds or even tar. The main impurities in the CO_2-rich feedstocks that may negatively affect biomethanation process include nitrogen and sulfur oxides, hydrogen sulfide, and heavy metals. Carbon monoxide can act as carbon source for biomethanation but in high concentrations may inhibit the microorganisms.

APPLICATIONS/IMPACT

Evaluating the environmental performance by utilizing life cycle assessment (LCA) can guide the development of biomethanation value chains to more environmentally sustainable direction. LCA enables to identify the specific life cycle phases where emissions are generated and thus highlights the key areas for improvement. This insight is crucial for implementing more sustainable methane production methods, ensuring that the adoption of biomethanation technology leads to reduced environmental impact and enhanced sustainability. Furthermore, the information of the effects of variations in the gaseous feedstock availability and composition guide in process design and in choosing right locations for the biomethanation processes in terms of the quality and availability of the CO_2-rich streams as well as H_2. Finally, the potential of converting CO_2 in biogas further to methane is high, and considering also other biogenic CO_2 sources further increases this potential, highlighting the applicability of biomethanation for methane production in the future.

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