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OPERATION OF PILOT SCALE BIOMETHANATION SYSTEM FOR UTILIZATION OF CO_2

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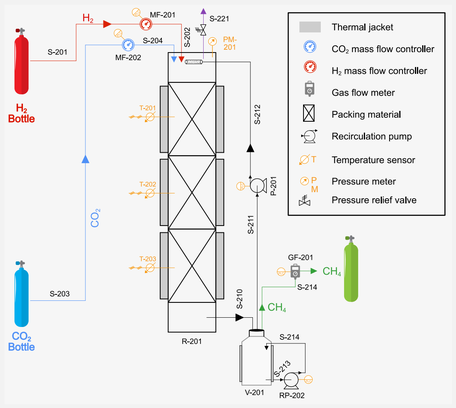

Core of the pilot-scale biomethanation system is a stainless steel trickle-bed continuous reactor (100 L), operating at 55 ± 2°C, with an anaerobic vessel for recirculating liquid inoculum.

The system's monitoring and data logging are overseen by a Programmable Logic Controller with remote access, allowing for automated operation, continuous parameter monitoring, and remote-control capabilities

- System performance was remained stable, with CH_4 concentrations in output gas consistently exceeding 95% over 300 days (Figure 1).
- At GRT 3h, the system achieved peak performance, with CH_4 concentration reaching 99.7%, showcasing near-complete conversion of CO_2 to methane.
- At GRT 2.5h process efficiency was persistent maintaining approximately 99% CH_4 content despite a temporary dip that never fell below 95.5%.
- At GRT 2h the system exhibited also high efficiency with CH_4 content remaining above 95%.
- At GRT 1.5 h, the pilot scale biomethanation system continued to exhibit a CH_4 content exceeding 95% for 10 consecutive days.

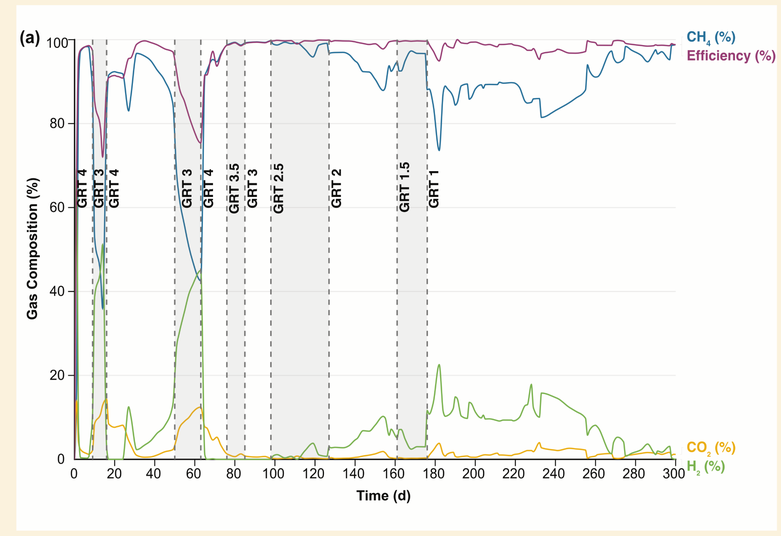

Figure 1a. Output gas composition (%) of CH_4, CO_2, and H_2 of the pilot unit during the different GRT of the operation

- A significant challenge was encountered when the GRT was decreased to 1 h. Methane concentration dropped below 70% on the 183rd day, probably due to limited gas-liquid mass transfer of H_2. The rapid flow rate at this GRT impeded effective contact between H_2 and the microbial consortia. The system successfully regained its processing efficiency by substituting a considerable portion of metabolic water with filtered digestate from a biogas reactor, regaining a CH_4 concentration greater than 90%.
- Despite the observed temporary spikes in VFA concentrations (Figure 2) following GRT adjustments, the system exhibited remarkable resilience, and maintained high methanation efficiency, as evidenced by the stable and high CH_4 content in the output gas. This indicated a well-balanced biomethanation process capable of adapting to nutrient supply variations and operational changes without significant detriment to system stability or efficiency.
- The observed pH fluctuations and their correlation with methanation performance across different GRTs emphasize the necessity of maintaining optimal pH levels to ensure the system's stability and operational efficacy, especially under varying operational conditions

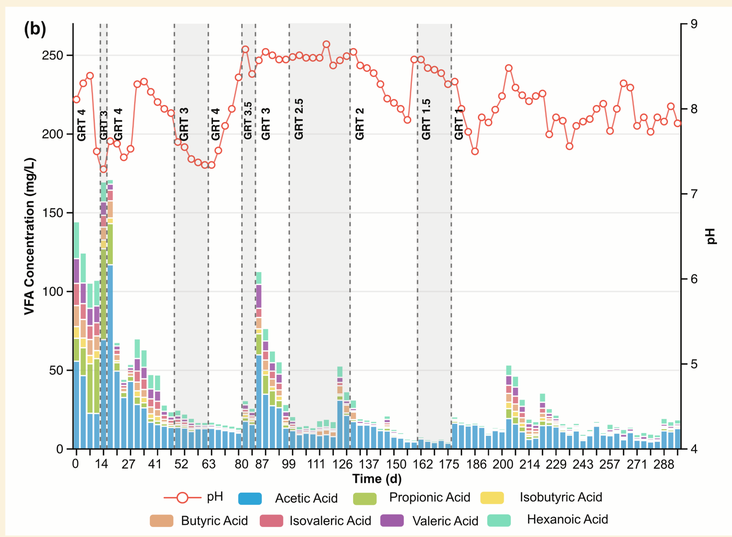

Figure 2. VFA concentrations (mg/L). Red line illustrates the pH during the different GRTs of the experiment

Table 1. Pilot unit operation progress indicators, comparison between targets and output

Progress indicators	Target	Output
Operation of the pilot unit for continuous ex-situ biomethanation	>180 days	**Accomplished** (300 days of operation)
Efficiency of ex-situ biomethanation pilot unit	>90% CH_4 in output gas	**Accomplished** (91-98% CH_4 in output gas)
Reduction of intermediate fermentation metabolites via microbial resource management	<1000g/L acetate concentration	**Accomplished** <0.12g/L acetate concentration

The operation of the prototype pilot methanation unit not only met the outlined targets as detailed in the LIFE CO_2toCH_4 project, as described in Table 1 but significantly exceeded the expectations set for these target values.

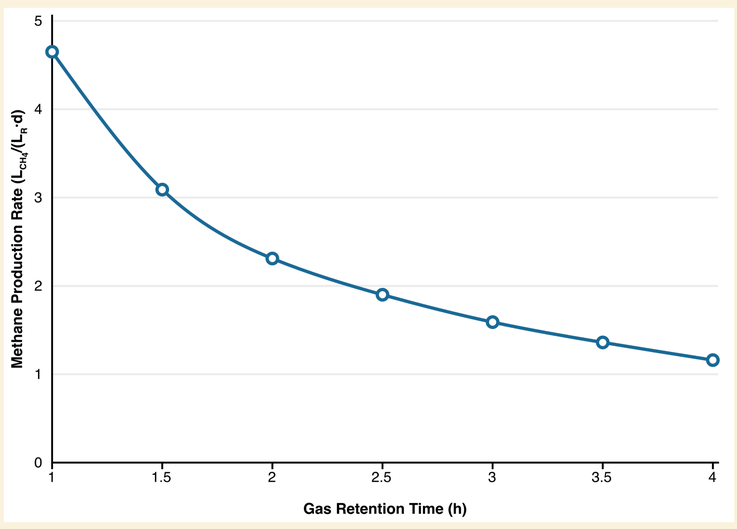

Figure 3. Methane Production Rate during pilot unit reactor operation GRTs.

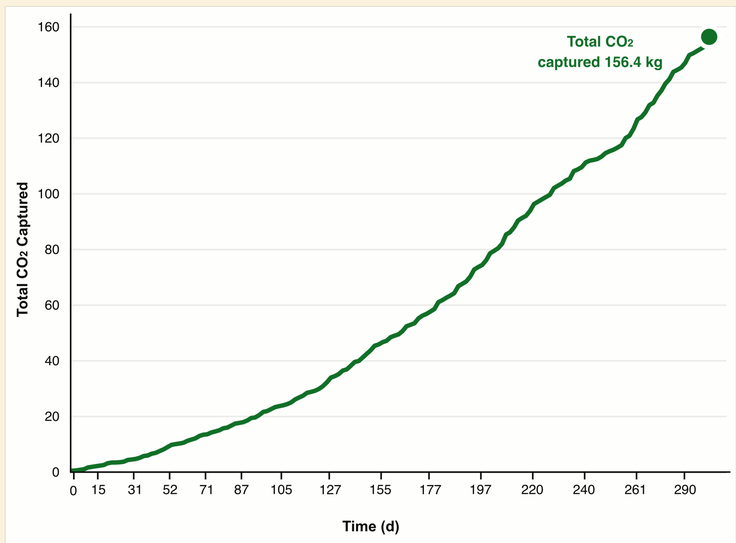

Figure 4. Total CO_2 (kg) captured during pilot unit operation.

Conclusions

For more than **300 days of operation**, the pilot unit successfully captured **more than 156 kg of CO_2** (Figure 4), effectively utilizing it as a feedstock in the biomethanation process.

Overall, the pilot scale biomethanation system showcased a **robust and adaptable biomethanation efficiency, capable of maintaining efficient performance and high CH_4 output across varying operational conditions**. The consistently low levels of VFAs across all GRTs underscored the operational stability of the unit, attributing the challenges encountered at shorter GRTs to factors beyond shifts towards less favorable metabolic pathways.

The highest recorded Methane Production Rate was 4.65 $L_{CH4}/(L_R \cdot d)$ which is indicative of the efficient gas-liquid mass transfer, suggests that **the biomethanation system could be scaled up effectively for larger-scale applications, maintaining high efficiency in methane production** (Figure 3).

The exceeding of expectations in this pilot unit operation is crucial as it offers a more comprehensive understanding of the system's capabilities and potential. It also provides a higher level of confidence in the technology, opening up opportunities for its **application in larger-scale setting that will be accomplished at the installations of the PPC Power Plant of Agios Dimitrios**.

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