Sustainability and Life Cycle Assessment of feedstock digestion systems

Voelklein, Markus.* Murphy, Jerry.
University College Cork, MaREI Centre, Environmental Research Institute, Bioenergy & Biofuels Research Group, Cork, Ireland
*Mvoelklein@ucc.ie

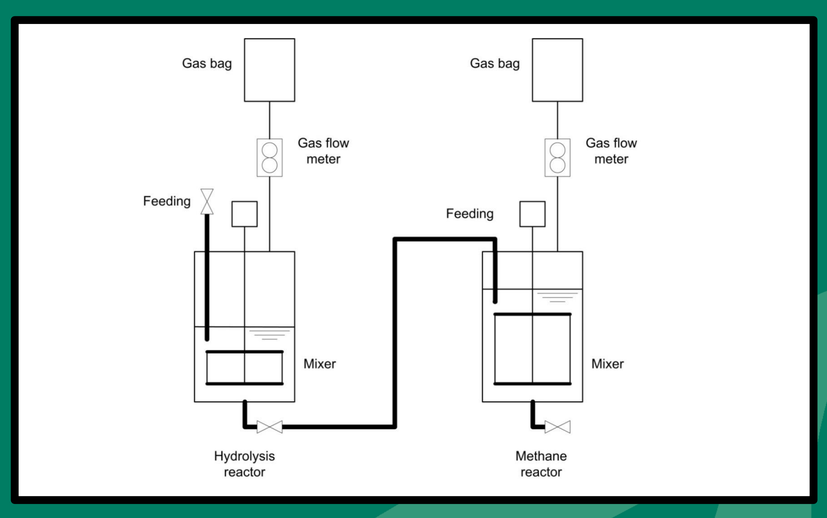
Funded by the European Union

Introduction

This project assesses innovative biomethane systems, such as multiphase digestion and in-situ biological methanation. This is carried out through detailed system analysis including energy and carbon balances, laboratory, assessment and general life cycle analyses.

2-stage digestion

The purpose of this study is to investigate the 2-stage fermentation process compared to the single-stage based on food waste.

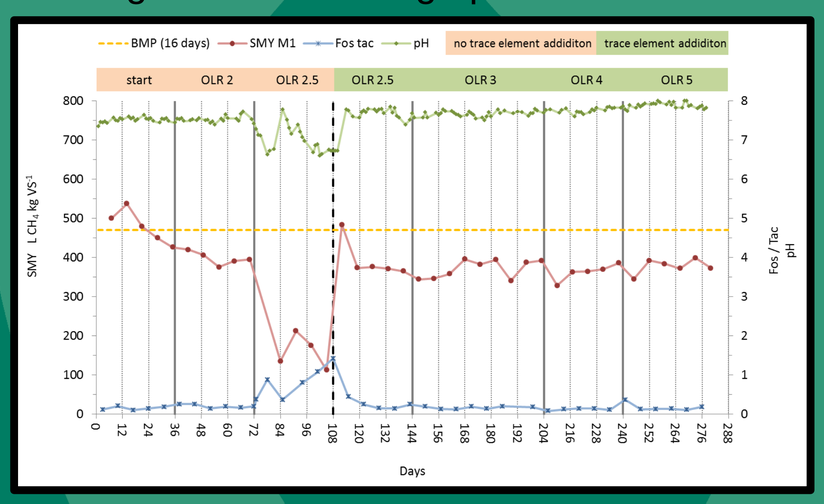


The system comprises an upstream acidifying hydrolysis reactor, producing hydrogen and carbon dioxide. The second methane reactor is dominated by the methanogenic phase, generating high concentrations of methane.

Key findings

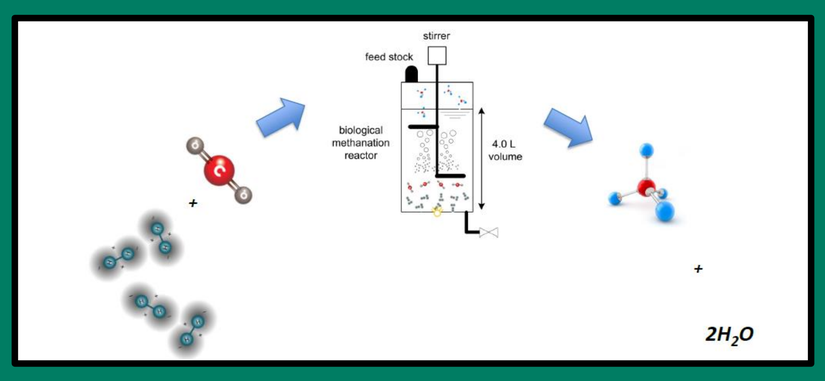
- ✓ The methane content increased by 14 % to 71 % in the two-phase system
- ✓ The SMY of the two-stage system exceeded the single-stage system by up to 23 %
- ✓ Food waste lacked essential trace elements causing VFA accumulation and reactor failure at 2.5 g VS L^{-1} d^{-1}
- ✓ Trace element addition enabled stable digestion up to 5 g VS L^{-1} d^{-1}

The diagram below illustrates the impact of trace elements at gradually increased loading rates in a 2-stage process.



Biological methanation

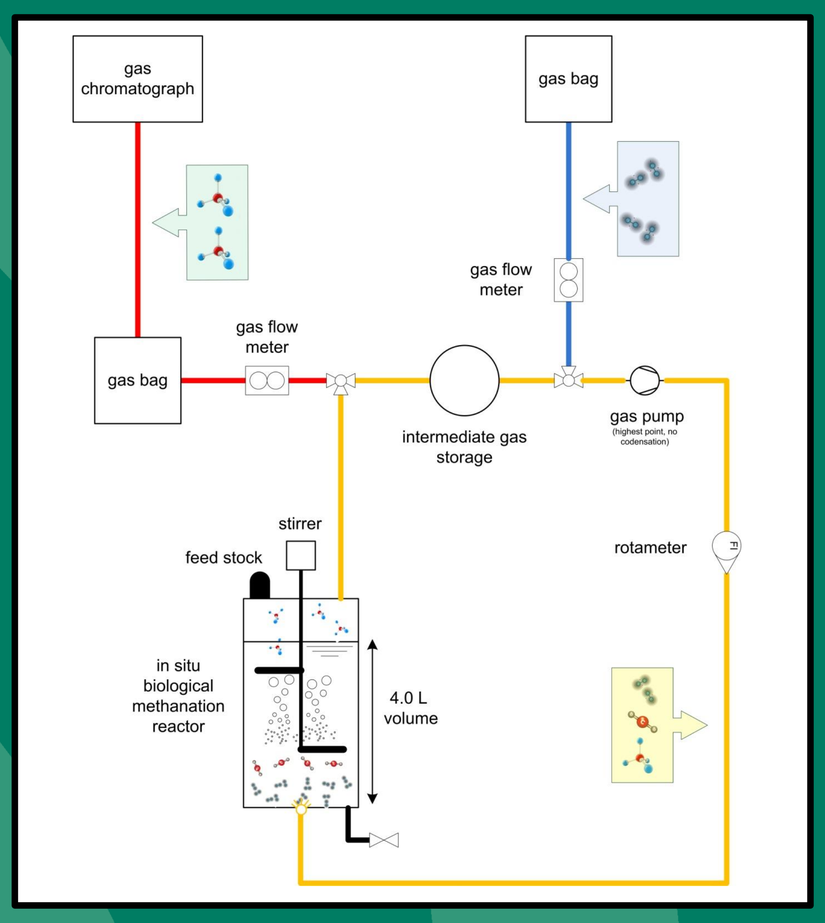
This biological methanation project focuses on efficient digestion systems and upgrading of biogas with external hydrogen from surplus electricity as described in the Sabatier equation. 2 moles of Hydrogen and 1 mole of carbon dioxide are naturally converted to 1 mole of methane and 2 moles of water in a biological methanation reactor.



Ideally the methane content in the biogas is enhanced to >95 Vol.-% and eligible for gas grid injection.

Lab experiment

In addition to the daily feedstock (source of methane and carbon dioxide), the necessary quantities of hydrogen are injected into a modified 5-litre lab scale reactor. A gas pump recirculates the produced biogas and hydrogen mixture to enhance contact phase and retention time for the Sabatier reaction. The carbon dioxide is thereby upgraded to biomethane.

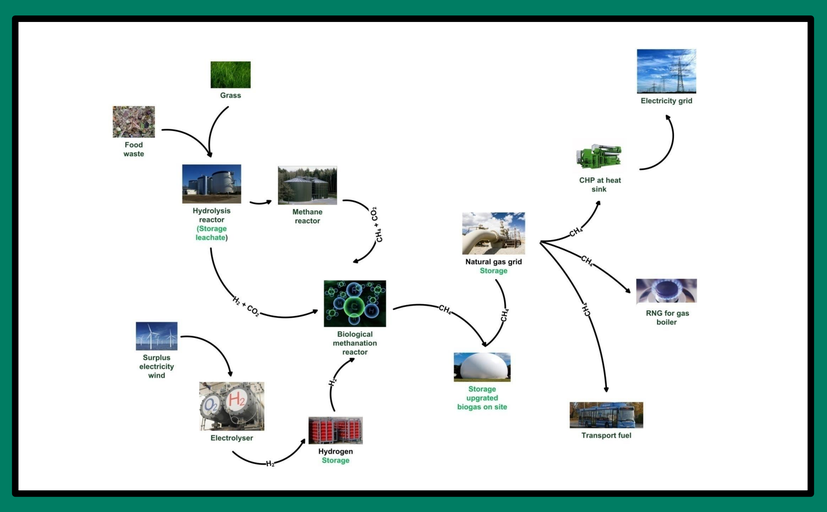


The final success of the upgrading process is determined by a gas chromatograph. As a consequence the methane production theoretically almost doubles and carbon dioxide is successfully removed.

The experiment is compared to a series of thermophilic high organic loading rate grass digesters without hydrogen injection, to compare results and a possible change in microbial community.

Life cycle assessment

In a future outlook the data of the lab scale biological methanation experiment will be implemented in a model of a full scale biogas plant as shown in the subsequent charts. Carbon and energy balances will provide the basis for LCA and GHG analysis addressing the sustainability of the process.



The produced biomethane can be utilized in transport, heating or electricity applications. In this scenario, the storage capability of biogas with the associated external hydrogen functions as a "battery" of the electricity grid.

Key performance indicators

- ✓ Efficiency of two-stage digestion as compared to single-stage
- ✓ Role of trace elements at variable loading rates in continuous digestion systems
- ✓ Thermophilic grass digestion as more efficient approach than mesophilic
- ✓ Development and operation of a lab scale in & ex-situ biological methanation reactor
- ✓ Life cycle assessment of a novel full scale biogas plant

Summary

➢ Specific methane yield of 2-stage outperforms 1-stage digestion

➢ Trace element supplementation essential for high performance and stable fermentation

➢ In-situ biological methanation increases biomethane yield and allows upgrading of biogas