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Biomass for Swiss Energy Future
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Direct Methanation of Biogas

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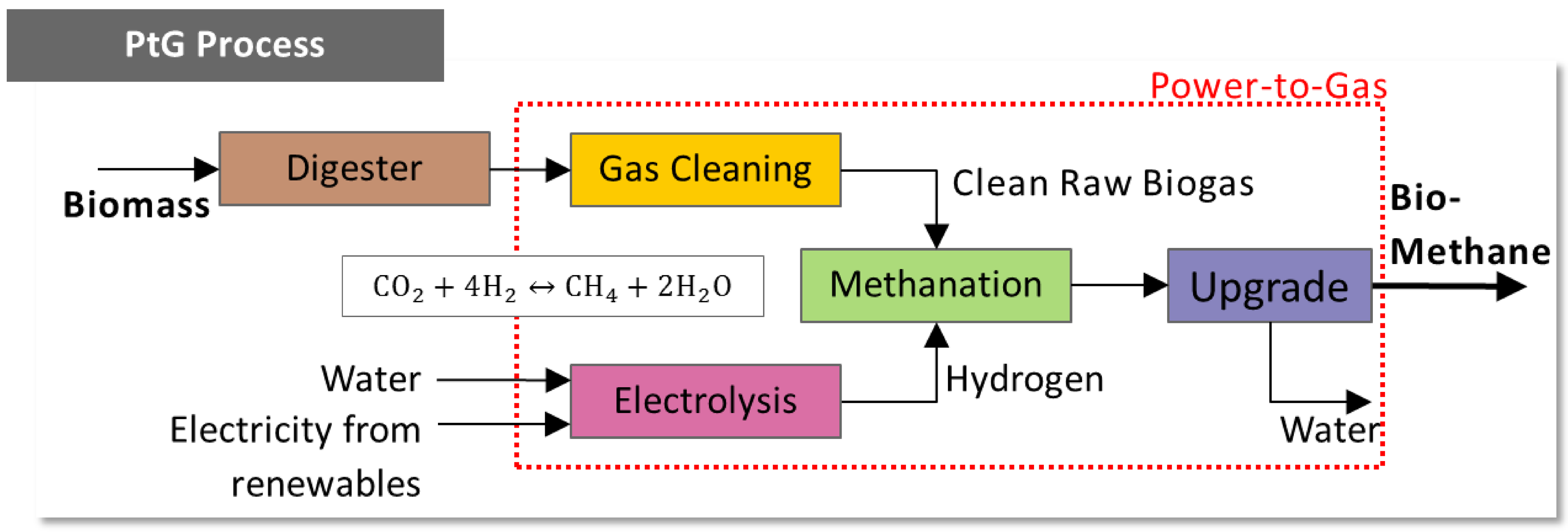
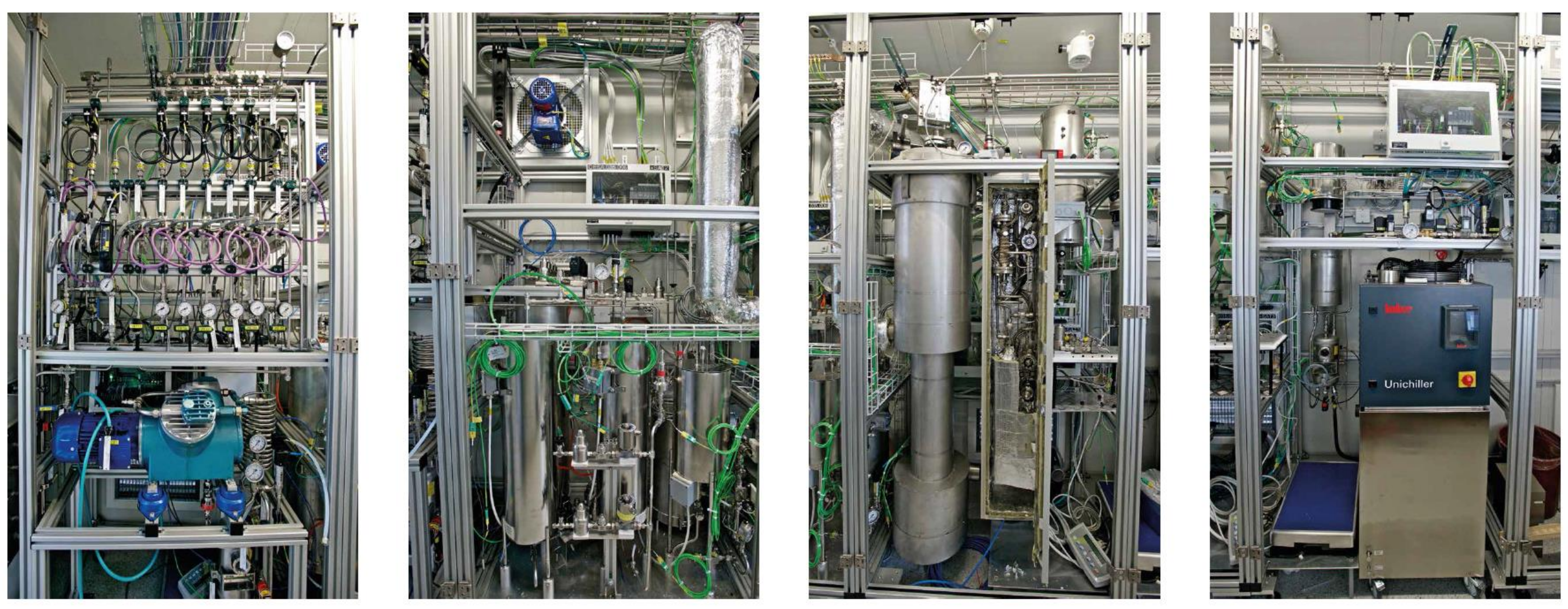
Introduction

While in many operating Power-to-Gas plants, CO_2 is first separated from the biogas and then further converted in a methanation step, a novel technology is validated in a collaboration between PSI and energie360°, a Swiss energy supplier. The idea is to omit the state-of-the-art CO_2 separation step (and the capital and operation costs related to it) and to feed the biogas completely to a catalytic fluidised bed reactor where the CO_2 is converted to methane. Due to excellent temperature control and continuous catalyst particle circulation within the reactor, fluidised bed methanation is less vulnerable to catalyst deactivation by carbon deposition.

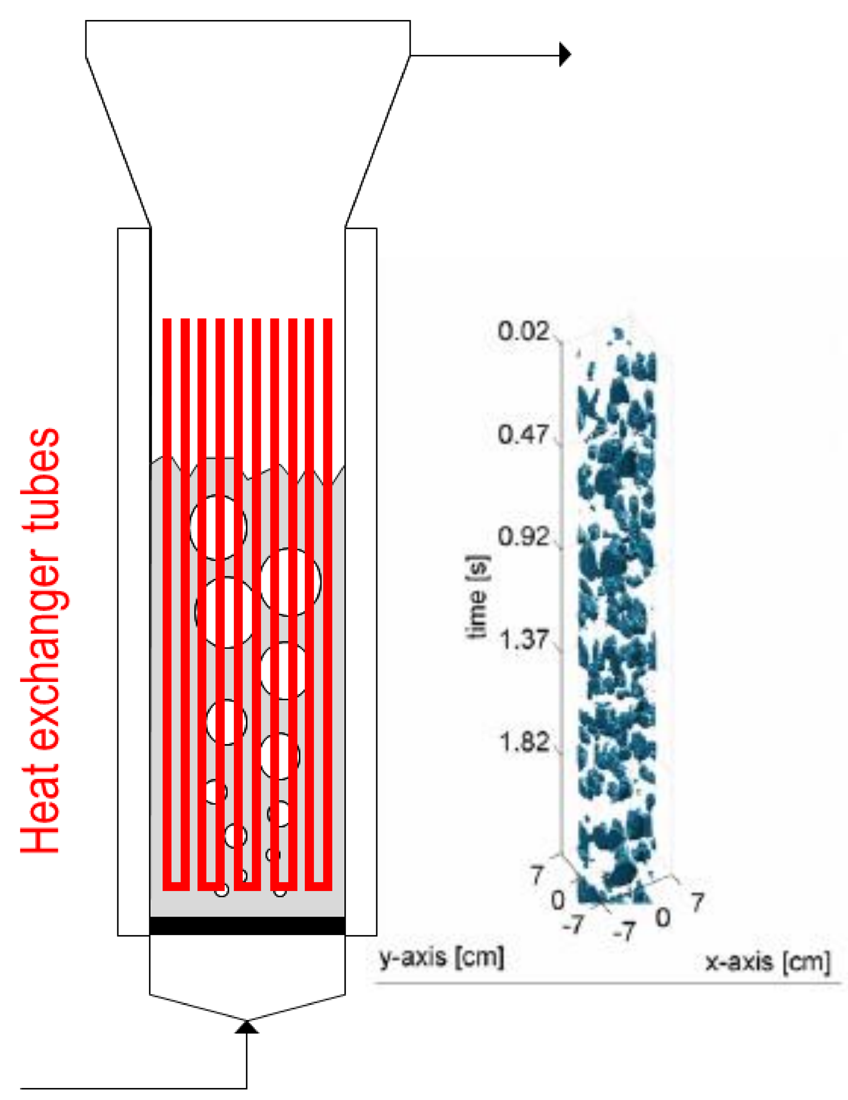


Experimental set-up

A 10 kWSNG scale fully automated set-up was built and commissioned that allows methanation of cleaned raw biogas with hydrogen from an electrolysis. Within a long duration test (1000h) using real gas from an anaerobic digester, catalyst stability and performance as well as the sorption based gas cleaning are demonstrated.



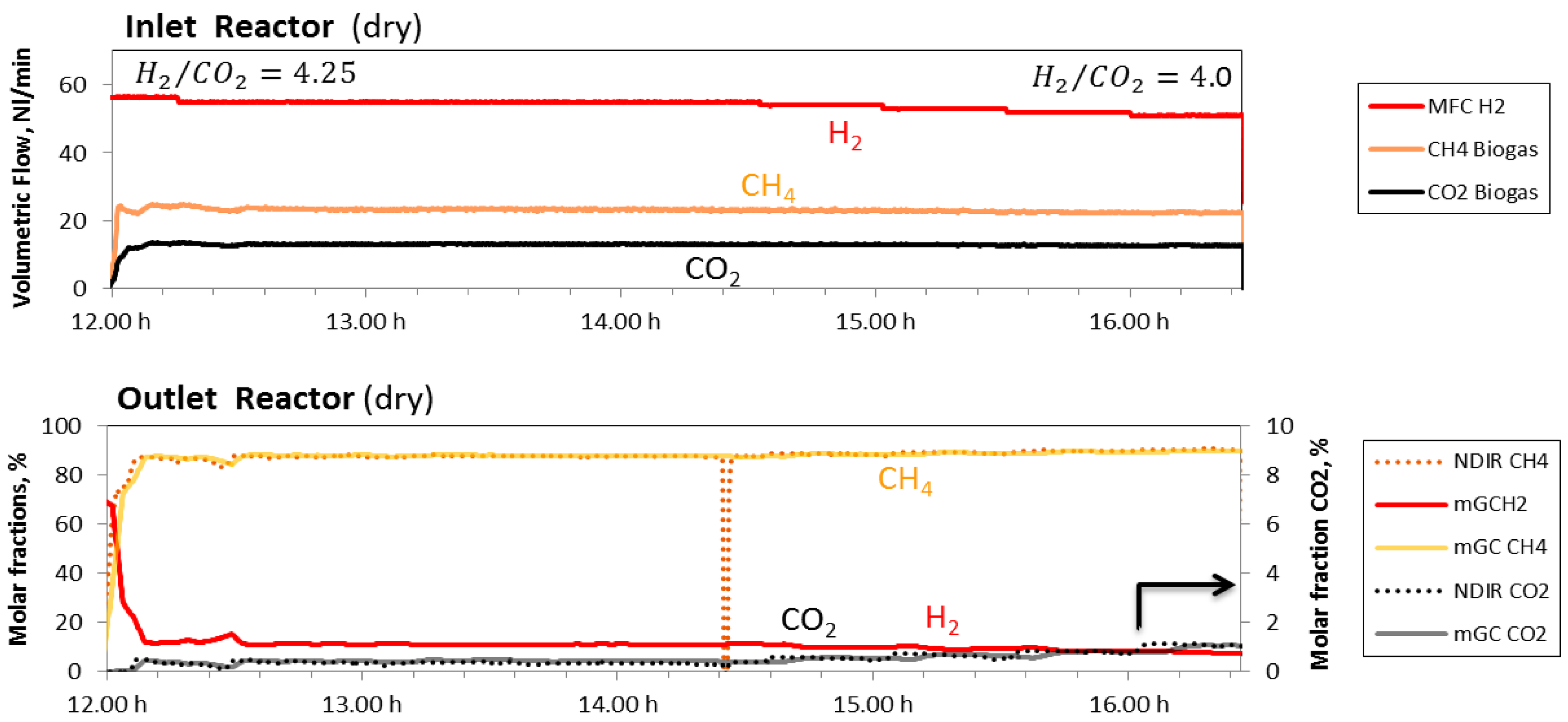
Gas mixing | Gas cleaning | Fluidised bed methanation | Water condensation



Fluidised bed

- Raw biogas and hydrogen flow through catalysts-particles (nickel-based)
- Immersed heat exchanger tubes remove heat of reaction
- Excellent heat transfer due to rising bubbles: nearly isothermal operation!
- Mass transfer depends on hydrodynamic conditions
- Robust against catalyst coking

Variation of H_2/CO_2 ratio

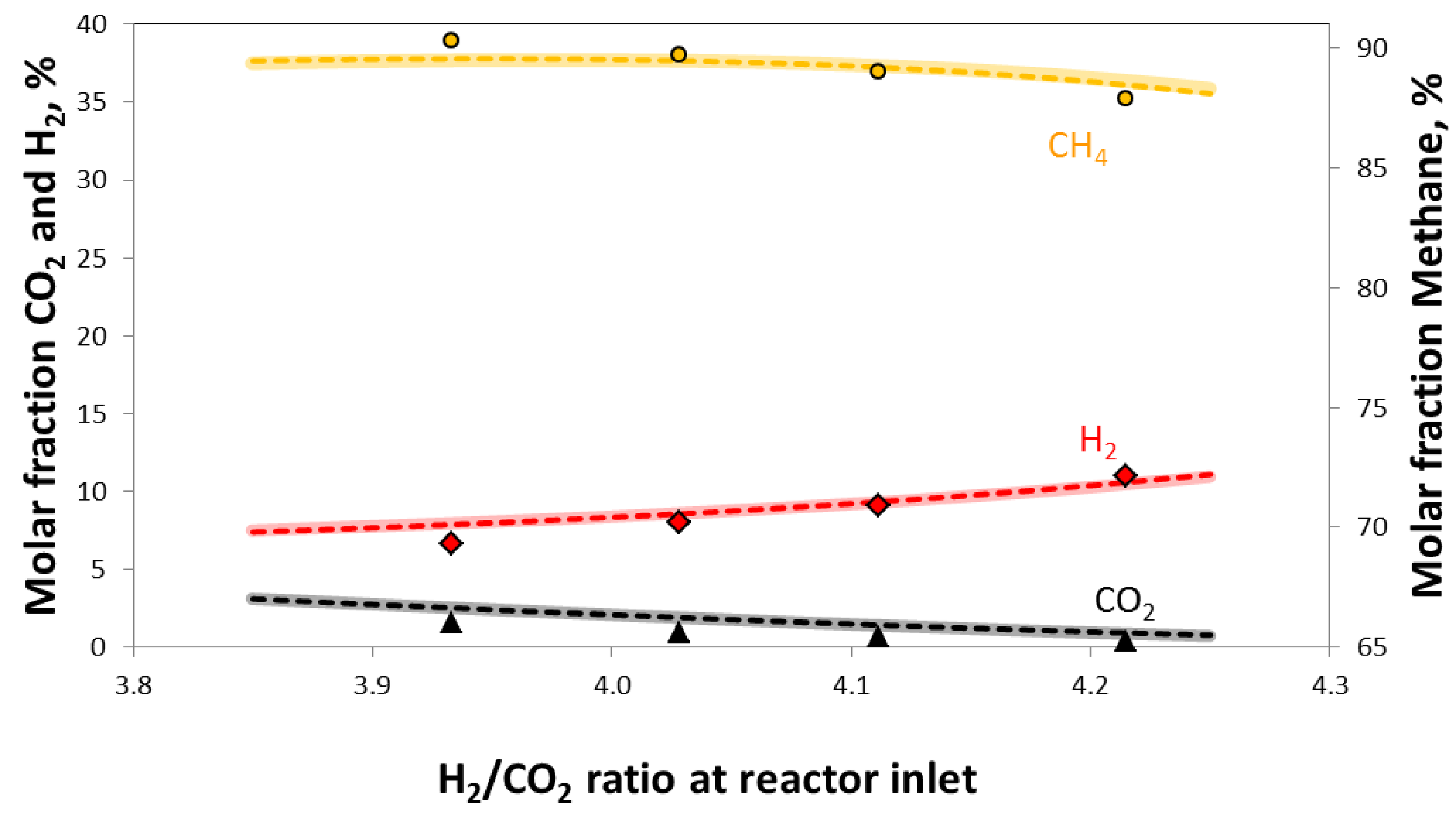


Flow rates at reactor inlet and molar fractions at reactor outlet during optimisation of H_2/CO_2 ratio

Experiment - model - thermodynamics

Limitation by kinetics at low temperatures and by thermodynamic equilibrium at higher temperatures causes an activity optimum which could be well predicted by modelling simulation. Besides temperature, also the H_2/CO_2 ratio turned out to be an important parameter determining final methane content. As shown in the figures, methane contents up to 90% can be reached this way. The gas is injected into the Natural Gas grid.

For further conversion beyond the equilibrium, condensation and a second methanation reactor will be needed. Alternatively, a membrane could be used to remove and recirculate hydrogen.



Experimental findings (symbols), thermodynamic equilibrium (full lines) and model prediction (dashed lines)

Conclusions

- Experiment shows high conversion close to thermodynamic equilibrium; 86-90% methane in injected gas
- The long duration test was conducted with optimised operation conditions. The test is accompanied by on-going catalyst sample characterisation and an extensive gas cleaning study to ensure removal of potential catalyst poisons from the biogas
- Technology is also suited for Power-to-Gas applications with wood gasification derived producer gas