

# Trickle-Bed Reactor For Biological Methanation

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## Energy storage

Energy storage systems become increasingly important due to far-reaching changes in the energy sector. The advantage of methane (substitute natural gas) as the product of the CO<sub>2</sub>-methanation process is its capability to be directly fed into the existing gas grid. This gas can be used for power generation as well as for heating systems, mobility or for process heat generation. The reaction proceeds according to the following chemical equation and shows, that CO<sub>2</sub> and H<sub>2</sub> are necessary reactants:



While presently CO<sub>2</sub> is mostly generated by biogas plants or combustion processes, H<sub>2</sub> is gained from electrolysis using excess electricity from renewable energy sources.

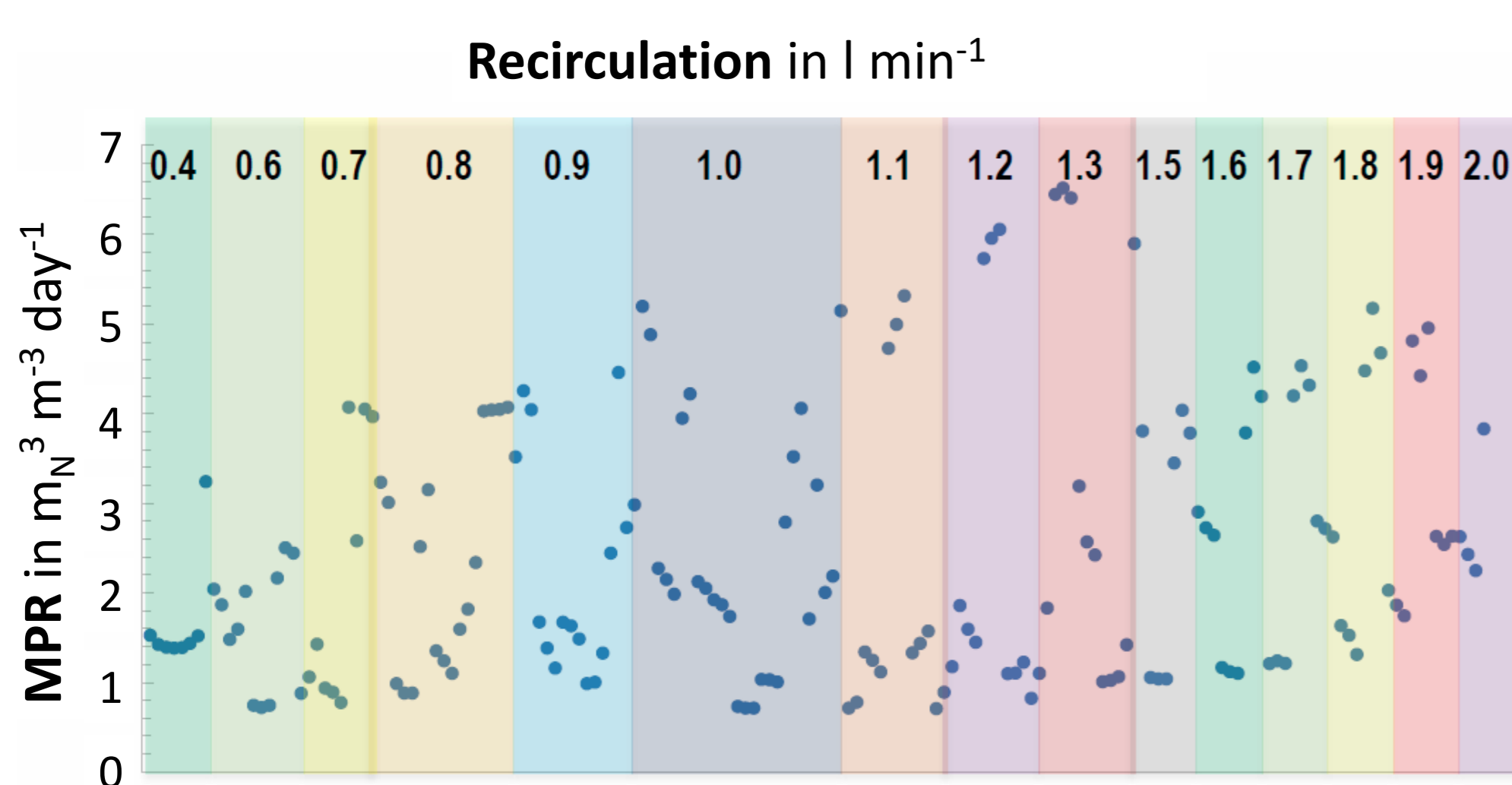


Figure 1: Methane production rate (MPR) per trickle zone over recirculation rate in the 5 liter trickle-bed reactor with pure culture

## Biological Methanation

The term "biological" describes the usage of Archaea instead of chemical catalysts to enhance the reaction. These Archaea live in an anaerobic liquid-phase metabolizing H<sub>2</sub> and CO<sub>2</sub> to CH<sub>4</sub>. Archaea are undemanding concerning their external environment and are therefore capable of adapting to different environments. The common process of methanation is operated chemical-catalytically. This technology is fully developed and currently superior to the biological methanation. However, the biological methanation holds certain advantages:

- low temperature and pressure possible
- short start-up time and easy operating at partial load
- biological catalyst, tolerates contaminations

One disadvantage is the lower methane production rate of the reactor (MPR<sub>R</sub>). It describes the production rate of methane per time and reactor volume. Further research on this topic will be necessary to rise the MPR.

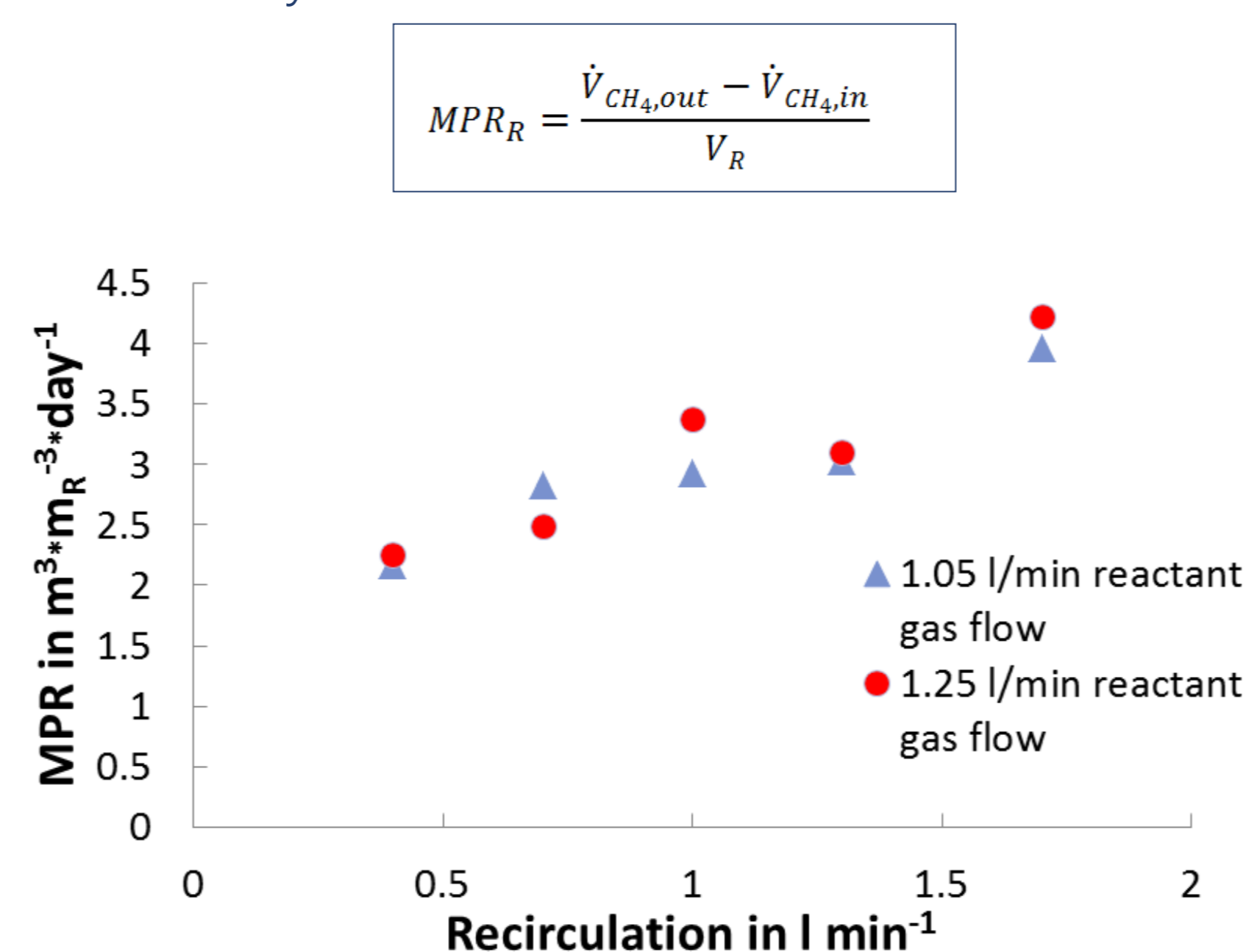


Figure 2: Continuous results of the 5 liter trickle-bed reactor with mixed culture

## Trickle-bed reactor

The challenge of the Biological CO<sub>2</sub>-Methanation lies in the low solubility of hydrogen in the liquid phase. H<sub>2</sub> is needed by the Archaea to maintain their metabolism. Reactors providing the required gas transfer rate are for example stirred tank reactors or the trickle-bed reactor. The EVT is running experiments with both reactor types on a small 5 liter-scale since 2016 with a pure culture. The results are the obvious pressure dependency and an unstable system behaviour. A pure culture is always sensitive to self-inhibition. That is why results are spread widely and constant results were rare. This shows figure 1, where the recirculation rate over the MPR is shown. Nevertheless, a maximum concentration of methane over 90% was reached. Changing the system to a mixed culture the system is more stable. Continuous results were stable as seen in figure 2.



Figure 3: 50 liter ORBIT-reactor

## Simulation of the 50 liter trickle-bed reactor

Several simulations were performed with ASPEN and MATLAB to better predict the concept of the trickle-bed reactor. The main goal hereby is to produce ≥ 98% of CH<sub>4</sub> with the 50 liter ORBIT-reactor for grid injection. Therefore we build the 50-liter reactor (fig 3) and simultaneously a 1D-model was constructed using mass transfer and absorption rate. As the background parameter, the countercurrent water flow, the gas flow of H<sub>2</sub> and CO<sub>2</sub>, the geometry of the reactor and the trickles were chosen. After the absorption of the gas the reaction rate of the microorganisms, converting the gas to CH<sub>4</sub>, was considered.

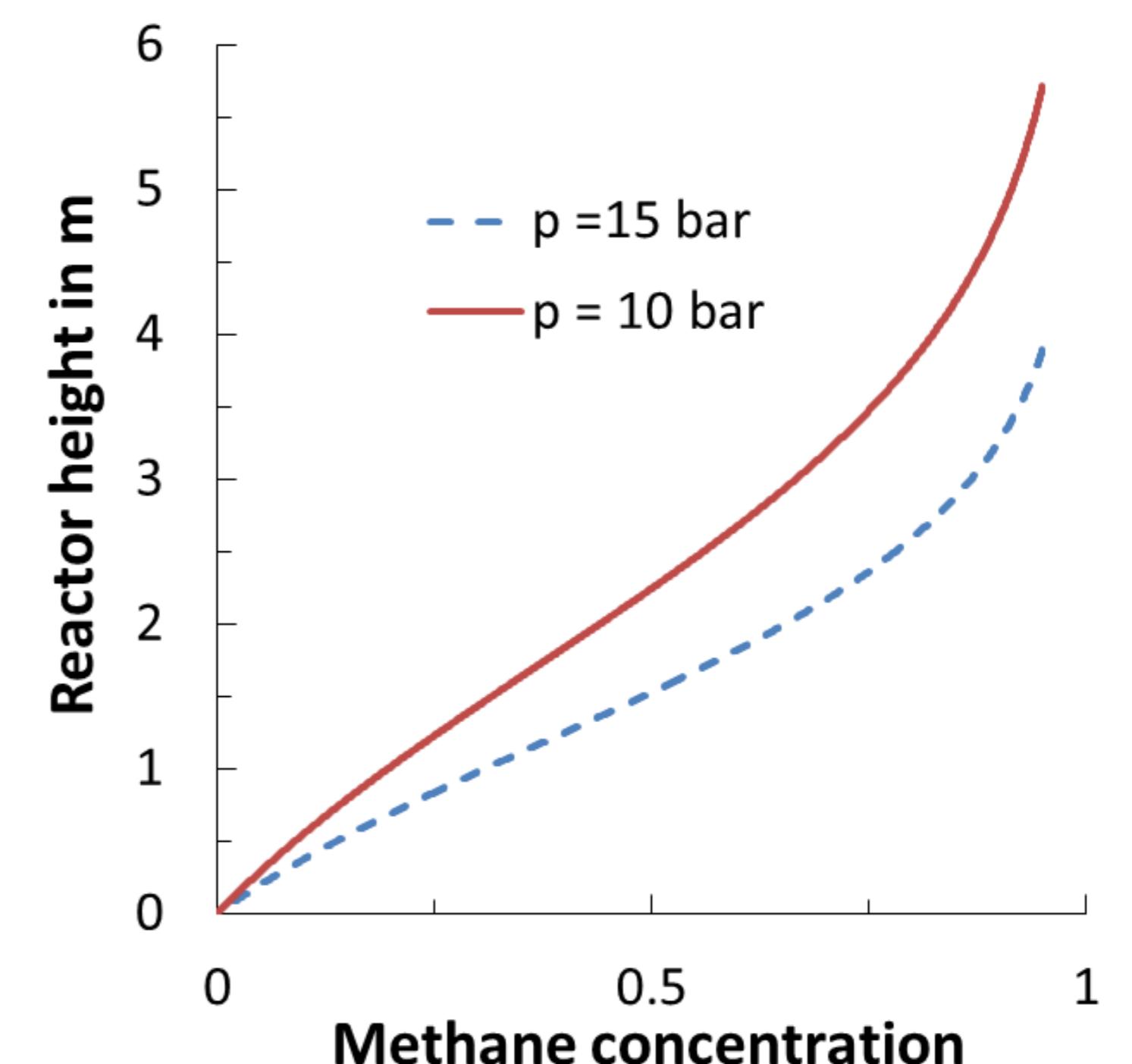


Figure 4: Methane concentration over reactor height at 10 and 15 bar

Simulations of the reactor concept demonstrate the importance of high pressure in the reactor. Towards the top of the reactor, the concentration of methane in the gas rises and the concentrations of feed gases decrease, leading to slow down the species transfer and thus to a reduction of the reaction kinetics. In consequence, targeting a high purity of methane requests high specific reactor heights, reducing the MPR. In Figure 3 the simulated course of the methane concentration over the height is shown.

## Conclusion

The biological CO<sub>2</sub>-Methanation in a trickle-bed reactor is a possibility to store energy as CH<sub>4</sub>. However, especially the MPR and the purity of CH<sub>4</sub> are challenges which need to be improved to make the system more economically. Therefore the 16 bar ORBIT-reactor was built.

