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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

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Trickle-Bed Reactor for Biological Methanation

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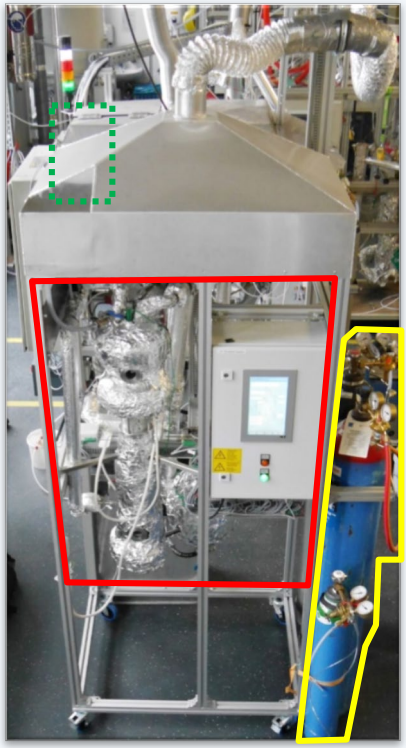
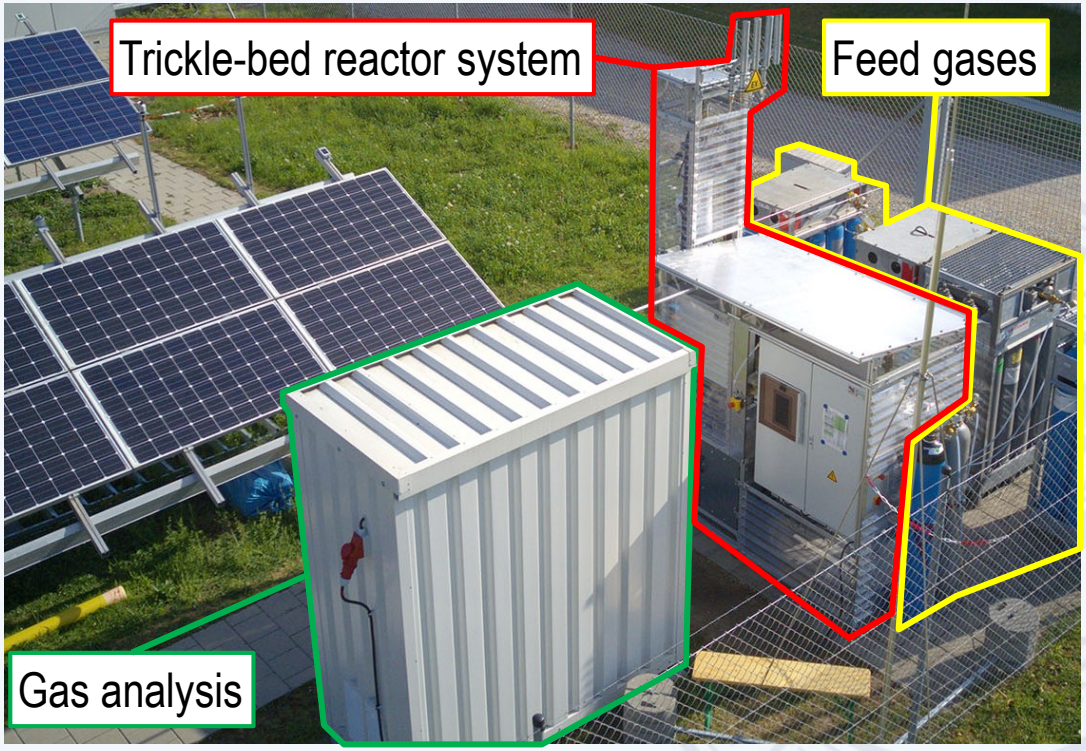
Lab-scale trickle-bed reactor in Nürnberg

Trickle-bed reactor in Regensburg (project ORBIT) ©Michael Heberl

TBRs for biological methanation



Lab-scale reactor at
FAU Erlangen-Nürnberg



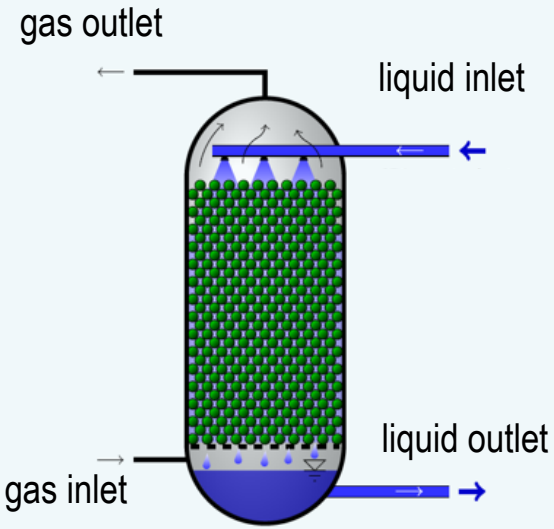
ORBIT reactor at OTH Regensburg

Two reactors – one concept

- Trickle-bed reactors (TBR) are used for enhanced solution of gases in a liquid
- High surface between liquid and gas phase
- Most common: gas and liquid in countercurrent

$$CO_2 + 4\,H_2 \Longrightarrow CH_4 + 2\,H_20$$

Lab-scale trickle-bed reactor in Nürnberg



Trickle-bed reactor in Regensburg (project ORBIT)

$$MPR_R = \frac{\dot{V}_{CH_4,out} - \dot{V}_{CH_4,in}}{V_R} \left[\frac{m^3}{h \cdot m^3} = h^{-1}\right]$$

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Two reactors – one concept

Parameter	Lab-scale reactor (experimental evaluation)	Prototype reactor (ORBIT)
Reactor volume	5 L	50 L
Pressure of the reactor Pressure of the gas grid	1 – 2.5 bar(a) -	14-15 bar(a) 12.5 bar(a)
Temperature	ca. 65°C	ca. 65°C
MPR_R	$1.5 \frac{Nm^3_{CH4}}{m^3_R \cdot h}$	$2 \frac{Nm^3_{CH4}}{m^3_R \cdot h}$ *
Educts feed gas	0.02 Nm^3/h H_2 0.005 Nm^3/h CO_2	0.26 Nm^3/h H_2 0.063 Nm^3/h CO_2
Maximum methane concentration	98 vol.-%	> 95 vol.-% *
Power (methane)	70 W	1000 W *
Recirculation rate	0.3 – 3.5 L min^{-1}	1 - 10 L min^{-1}
Random packing	Bioflow 9 (RVT)	variable
Microorganisms	pure culture & mixed culture	pure culture
Operation mode	continuous	continuous

Trickle-bed reactor in Regensburg (ORBIT)

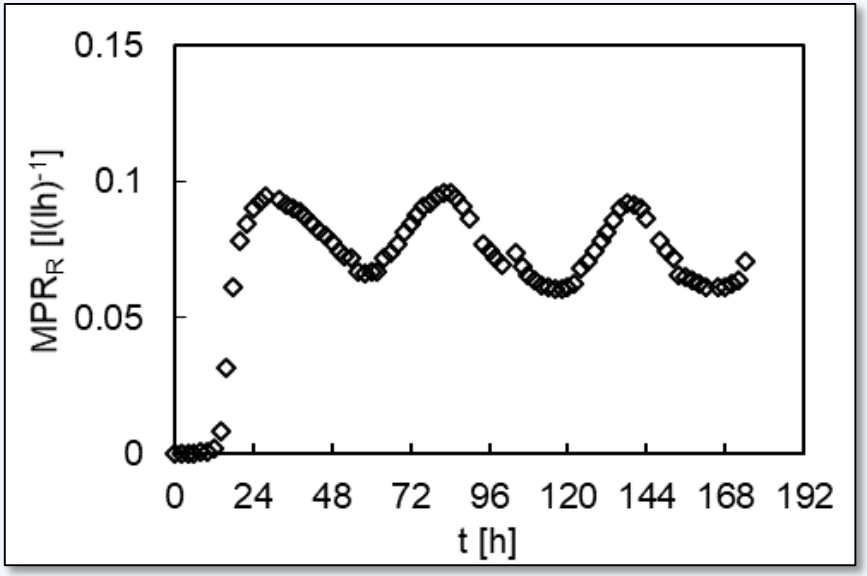
Lab-scale trickle-bed reactor in Nürnberg

* state of design

Methanation with a pure culture

- Experiments with special archaea culture
- Fluctuating methane production observed without apparent cause
- Pure culture tends to self inhibition

⇒ Application of a mixed culture

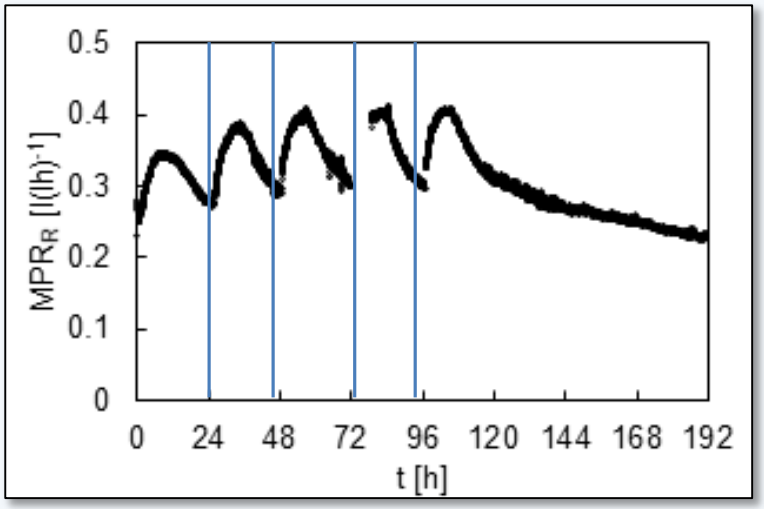


MPR fluctuation of the pure culture

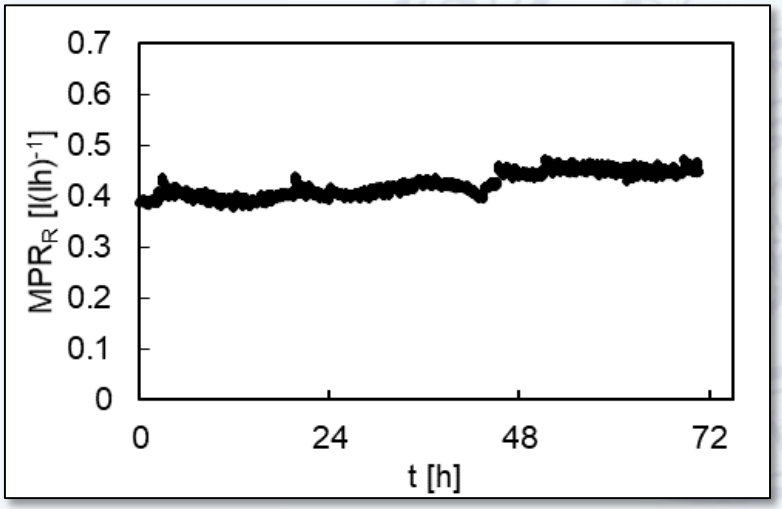
TBR at Nuremberg and the trickle zone

Mixed Culture

- Biogas digestate includes nutrients and several mircroorganisms
- Biogas digestate was added to the pure archaea culture
- The combination stables the system (most recent 10 months without changing the culture)
- Resulting in a higher performance level and less fluctuations
- Fluctuations caused by nutrient media feed (left figure)
- After adding the dosing pump the nutrient media was added continuous (right figure)



Mixed culture with daily adding of nutrient media



Mixed culture with continous adding of nutrient media

Mixed culture parameter studies

- The same culture stayed in the reactor for months
- Experiment started (t = 0) with the change of one parameter
- Before the experiment the reactor performed in a baseload to keep the microorganisms (MOs) alive and active
- Semi-continuous or continuous feed of nutrition media
- There are two options of experimental process:

Changing the parameters ongoing

	Pressure (bar_{abs})	Time (h)
Baseload	2	2
Parameter step 1	1.5	1
Parameter step 2	1.6	1
Parameter step 3	1.7	1
Parameter step 4	1.8	1
Parameter step 5	1.9	1
…	…	…
Drain of liquid		

- \+ quick
- \+ adaption of MOs to pressure
- − exhaustion of MOs can occur (more nutrition media required)

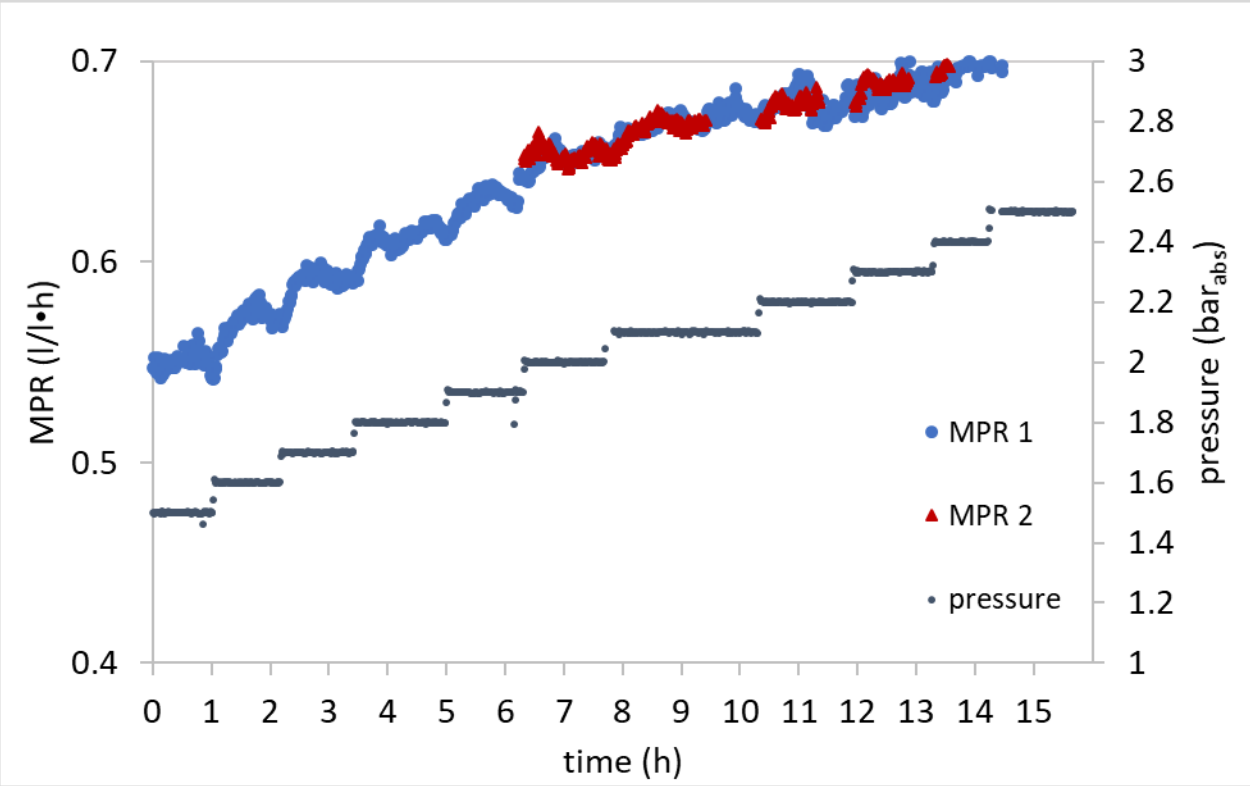
Going back to the baseload after each change

	Pressure (bar_{abs})	Time (h)
Baseload	2	2
Parameter step 1	1.5	5
Baseload	2	5
Drain of liquid		
Baseload	2	2
Parameter step 2	2.5	5
Baseload	2	5
Drain of liquid		

- \+ exactly the same initial situation at every parameter step
- − slow

Mixed Culture – pressure (1)

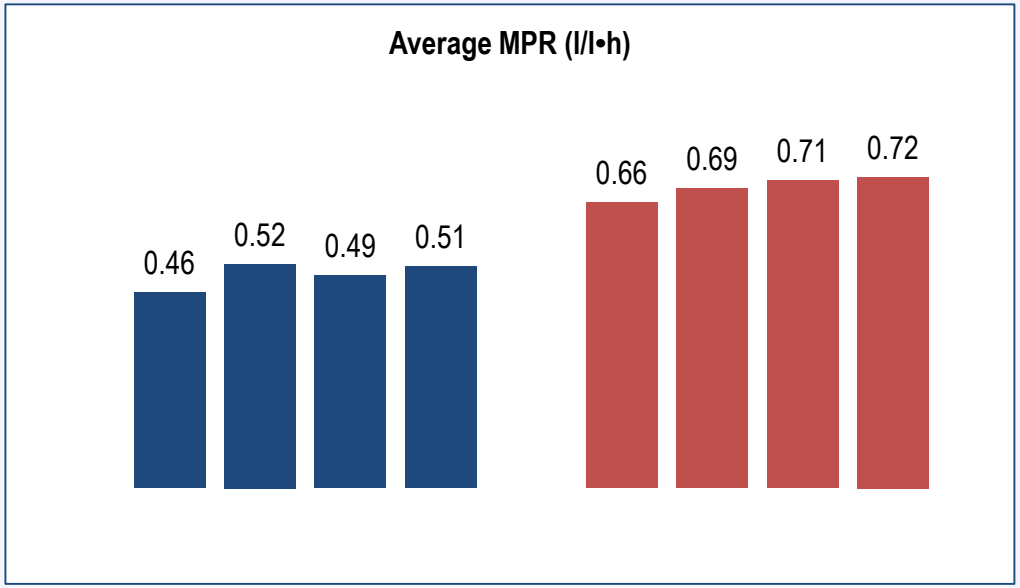
Pressure analyzing by increasing the pressure about every hour



- Increasing the pressure led to a higher MPR (better mass transfer)
- A validation one month later (red) showed quite similar results

Mixed Culture – pressure (2)

Pressure analyzing by going back to the baseload after each change



4 times:

	Pressure (bar_{abs})	Time (h)
Baseload	2	2
Parameter step 1	1.5	5
Baseload	2	5
Drain of nutrition		
Baseload	2	2
Parameter step 2	2.5	5
Baseload	2	5
Drain of nutrition		

- Similar results as before
- Increasing of the pressure resulted in a higher MPR (better mass transfer)
- Still a variation “form of the day”

Summary

1. Biological Methanation
- One option for energy storage by production of renewable methane (SNG)
- TBR is a promising reactor system for the biological methanation

2. Lab-scale TBR
- Mixed culture shows better results
- High pressure is advantageous for biological methanation
- Recirculation rate and nutried media feed have direct influence on the performance
- Lab-scale reactor systems work well

3. ORBIT-reactor
- Upscale of the lab-scale TBR
- Experiments just started with pure culture at OTH and University Regensburg

4. Outlook
- Optimizing the amount of nutrition for the lab-scale reactor
- Experimental analysis of the ORBIT-reactor
- Feed the gas grid with continuously produced SNG from the ORBIT-reactor