FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
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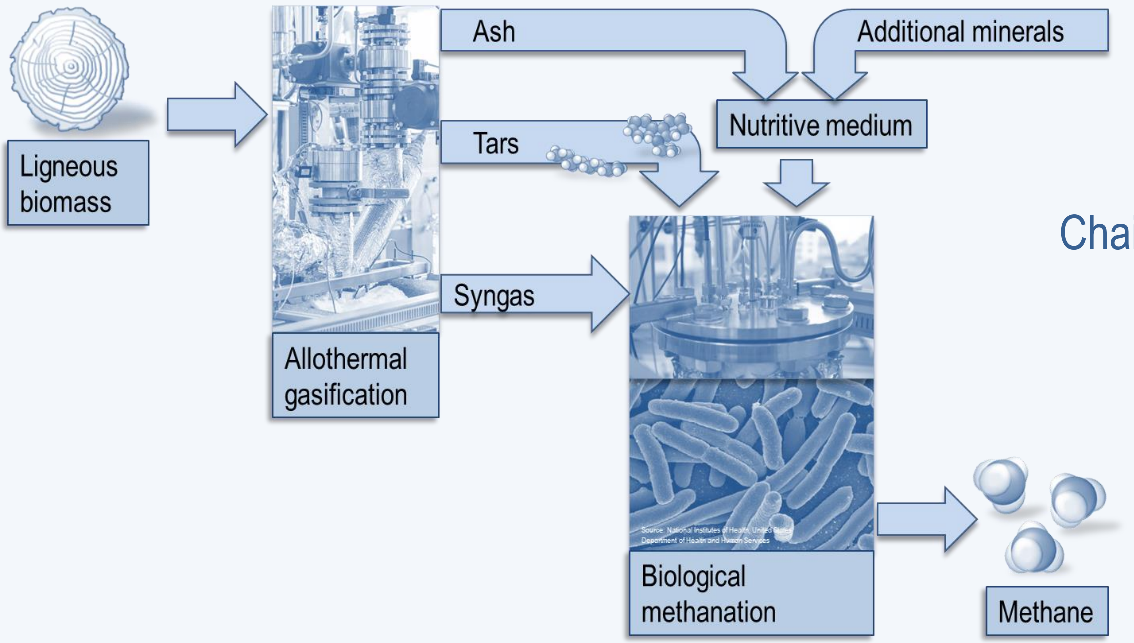
26th EUROPEAN BIOMASS CONFERENCE

Direct Biological Methanation of the Synthesis Gas of an Allothermal Wood Gasifier



May 17, 2018

Thomas Trabold, M.Sc.
Chair of Energy Process Engineering
Friedrich-Alexander University
Erlangen-Nürnberg

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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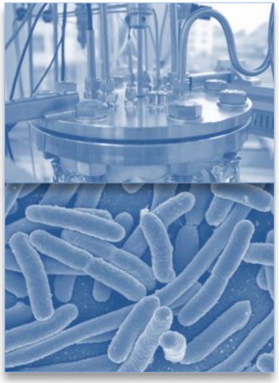


BMWi Project 03KB097

Ash-to-Gas

Microbiological methanation with hydrogen and nutrient solution out of the thermal gasification of biomass and its residues

Term 12/2015-05/2018

Bundesministerium für Wirtschaft und Energie

Projektträger Jülich Forschungszentrum Jülich

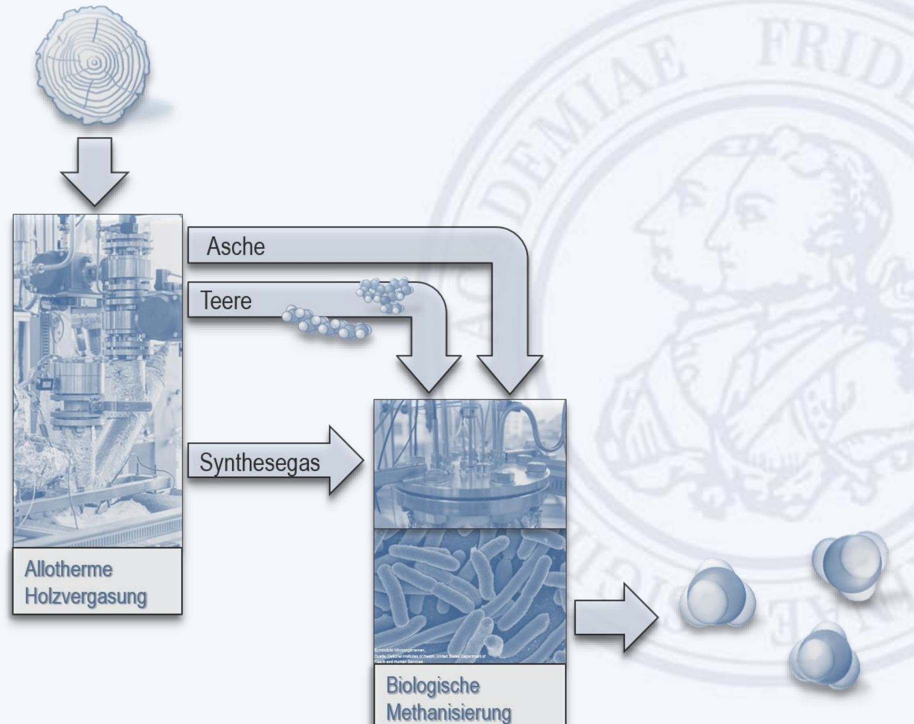
Energetische Biomassenutzung

- The project addresses the substitute natural gas (SNG) production:

  Biological methanation of gasified wood

- Main objects: Proof-of-Concept for the coupling of wood gasifier and biological methanation; Usage of gasification residues as nutrient

- Methods: Construction of a CSTR for the biological methanation, experimental research, proof of vitality via microscopy



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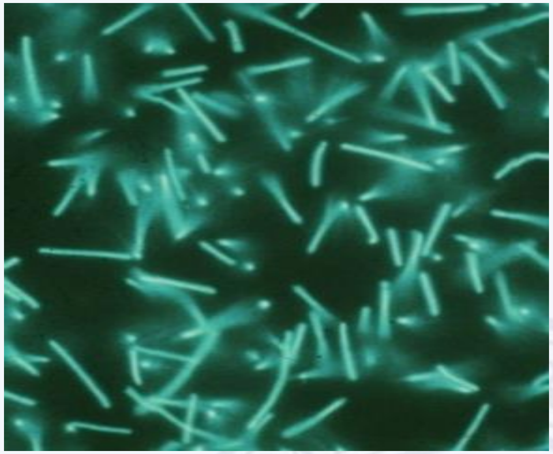
Archaea and reaction equations

- Besides bacteria and eukaryota, archaea are one of the three domains of cellular life
- Some strains of archaea are able to build methane out of different educts like H_2, CO_2, CO, acetates, and others
- Methanogens live in ecological niches, like cow craws, black smokers, marshes



Source: Institute of Microbiology and Archaea Centre, University of Regensburg

Metabolism of CO_2:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O$$

Stochiometric H_2 to CO_2 ratio of 4:1

Methane building rate (MBR):

$$MBR = \frac{normal\ volume\ of\ methane}{volume\ of\ fermenter \cdot time}$$

Metabolism of CO:

direct:

$$CO + 3\,H_2 \rightarrow CH_4 + H_2O$$

Indirect:

$$CO + H_2O \rightarrow CO_2 + H_2$$
$$4\,H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

$$4\,CO + 2H_2O \rightarrow CH_4 + 3CO_2$$

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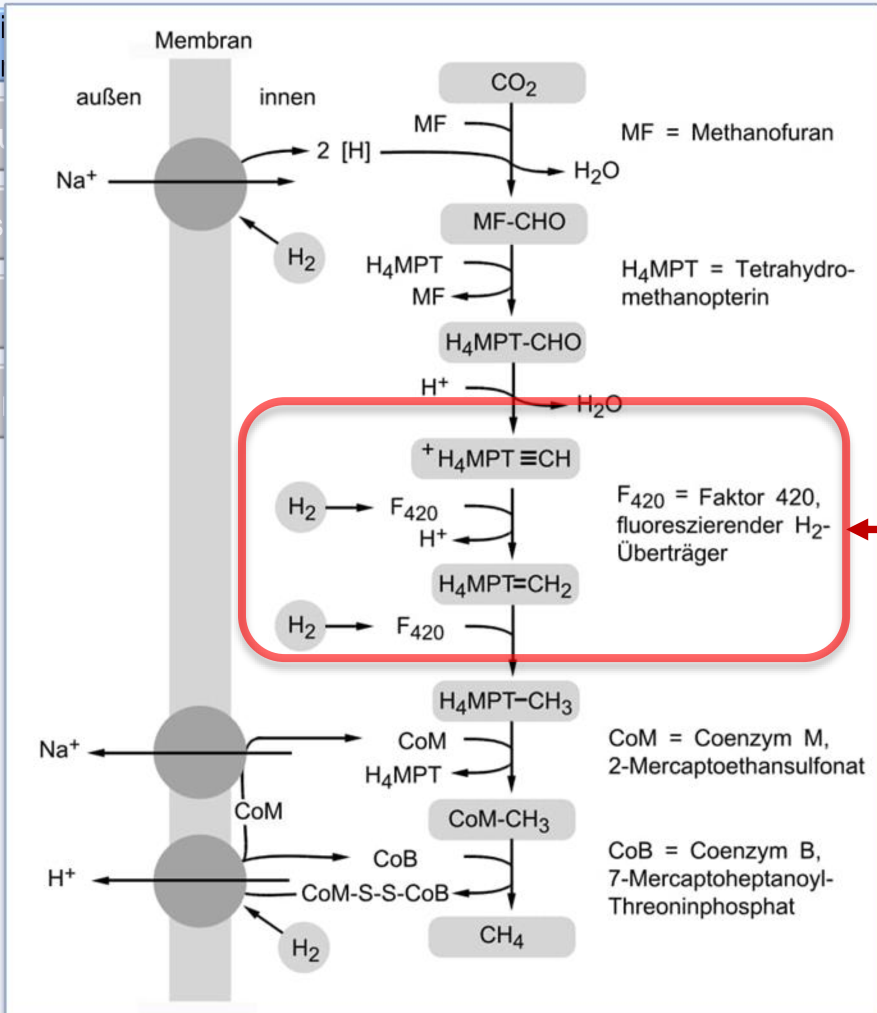
Biochemistry of biological methanation



[1] Cypionka, H. (2010). *Grundlagen der Mikrobiologie* (4th ed.). Springer. pp. 210-211

Methanation

↓

Need for Co-factor F420

↓

Fluorescence visible

Continuously stirred tank reactor (CSTR)

Parameters:

- Volume: 6,8 l
- Pressure: up to 3,6 bar(a)
- Temperature: 30 to 80°C
- Agitator speed: up to 3000rpm
- Operation mode: continuous or batch
- Educts: H_2, CO_2, CO
- Gas volume flow: 50 to 300 NmL/min
- Stirrer: Aeration stirrer Ø 72 mm
- Steel: 1.4307, 1.4404, 1.4404

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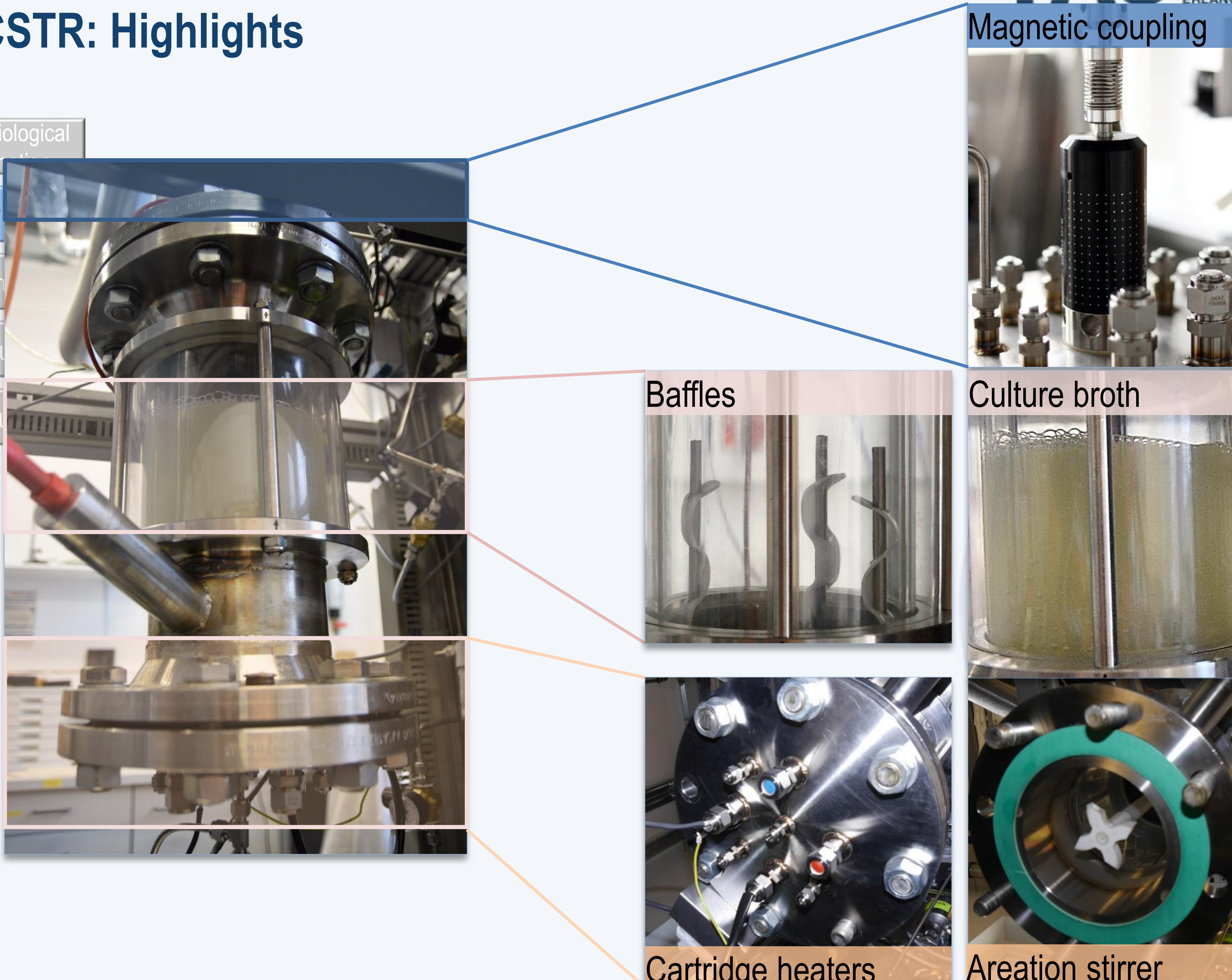
CSTR: Highlights

Basics biological methan
Facility
Experimen
Resu
Concl



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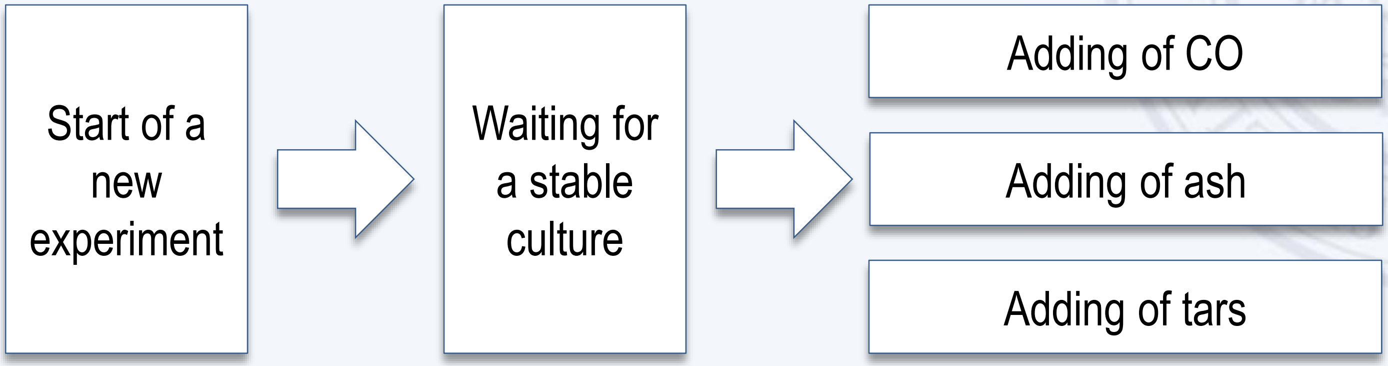
Structure of experiments

- Initial point:
  Culture fed with stoichiometric ratio of H_2:CO_2
- Approach:
  Adding of synthetic components to represent parts of the real syngas of the gasification
- Added components are:
  - CO
  - Gasification ash
  - Tars (toluene, methylnaphthalene and acenaphtene)



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Parameters of experiments

- CO:
  - Adding 20 vol.-% to the stoichiometric ratio of H_2:CO_2
  - Switch to expected composition of gasification syngas without adjustment of stoichiometric ratio (H_2 is 40, CO_2 is 24,CO is 18 and N_2 (same as the amount of CH_4, assuming CH_4 as inert gas) is 18 vol.-%)
- Gasification ash:
  - Produced under definded parameters
  - Given dosage is 0.043 g/d, orientated to an MBR = 10 NL/(L·d), fuel is wood pellets with an ash share of 0.5%-weight, assuming the syngas carrying all of the contained ash
- Tars:
  - 150h of experiment per tar component
  - 6.3 g/d for toluene and methylnaphthalene, following the same orientation as for the ash, assuming feed gas to carry 20 g/Nm³ of the tar component
  - 2 g acenaphtene added only once

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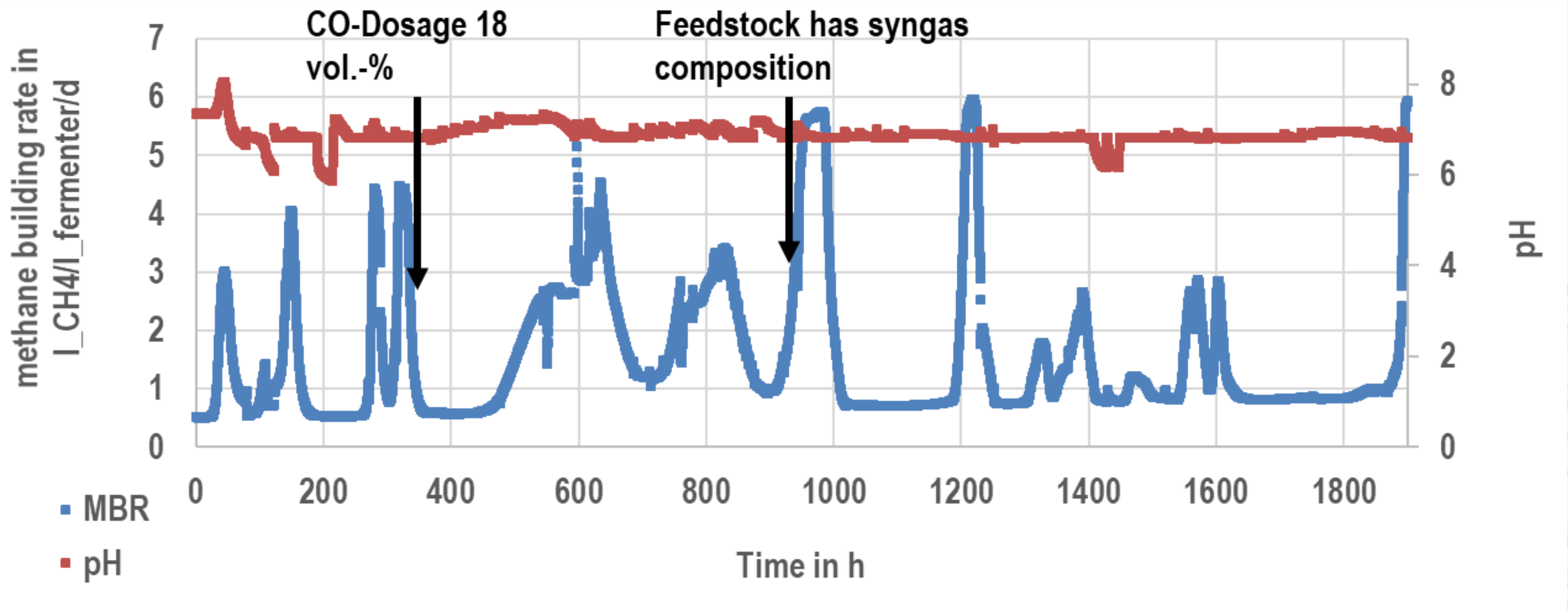
Results of adding CO



- fluctuation of MBR is in the usual frame, monitored in all measurements with the presented CSTR. This fluctuation cannot be explained, yet. Assumpted reasons: Solubles out of the used materials and inhibition of the culture through by-products
- lag periods of MBR are longer under CO-influence
- MBR stays at usual level
- Measurements show: CO is metabolized

CO is not a critical component, but can be turned to CH_4

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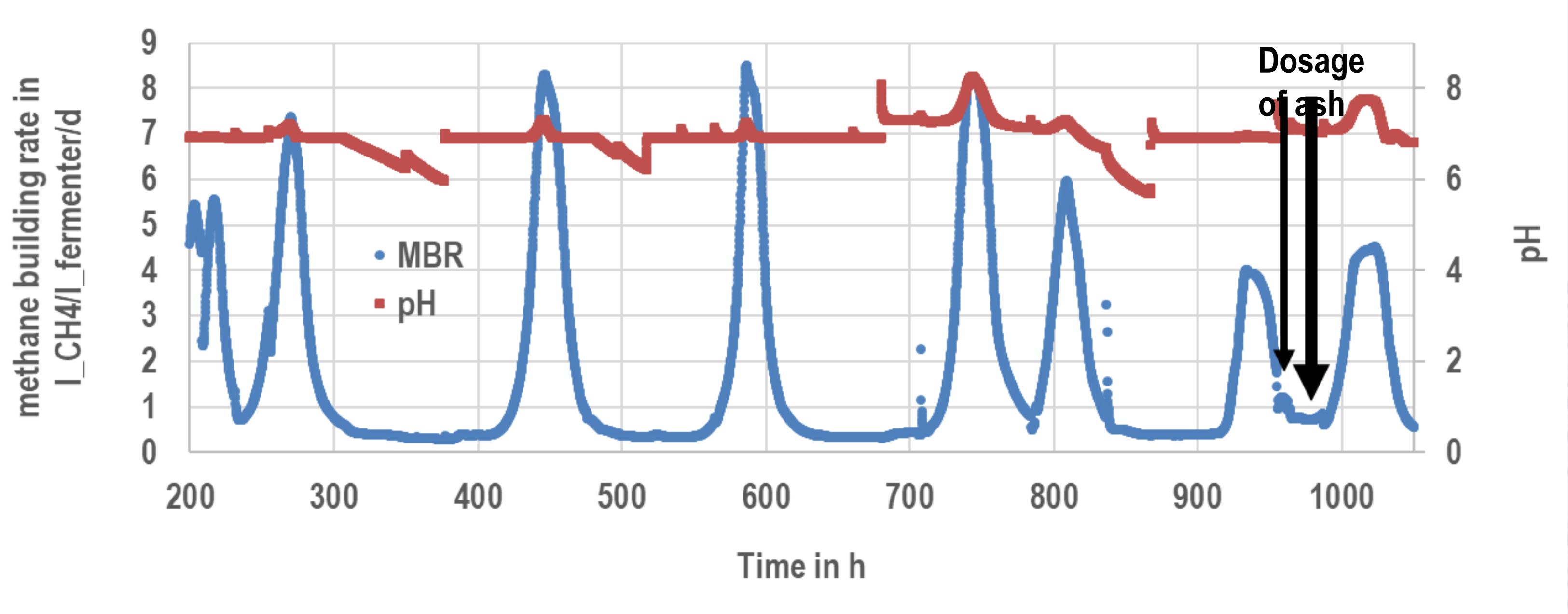
Results of adding ash

- Basics biolo methanati
- Facility se
- Experimental
- Results
- Conclusi



- fluctuation of MBR is in the usual frame
- Ash dosage at a parallel builded trickle bed reactor leaded to stalling of the culture
- Ash dosage in CSTR does not have a visible effect
- Probable reason: Not-ideal living conditions can lead to incomplete building of cellwalls. High shear forces due to stirrer prevent from agglomeration.

Ash dosage has no visible effect in CSTR

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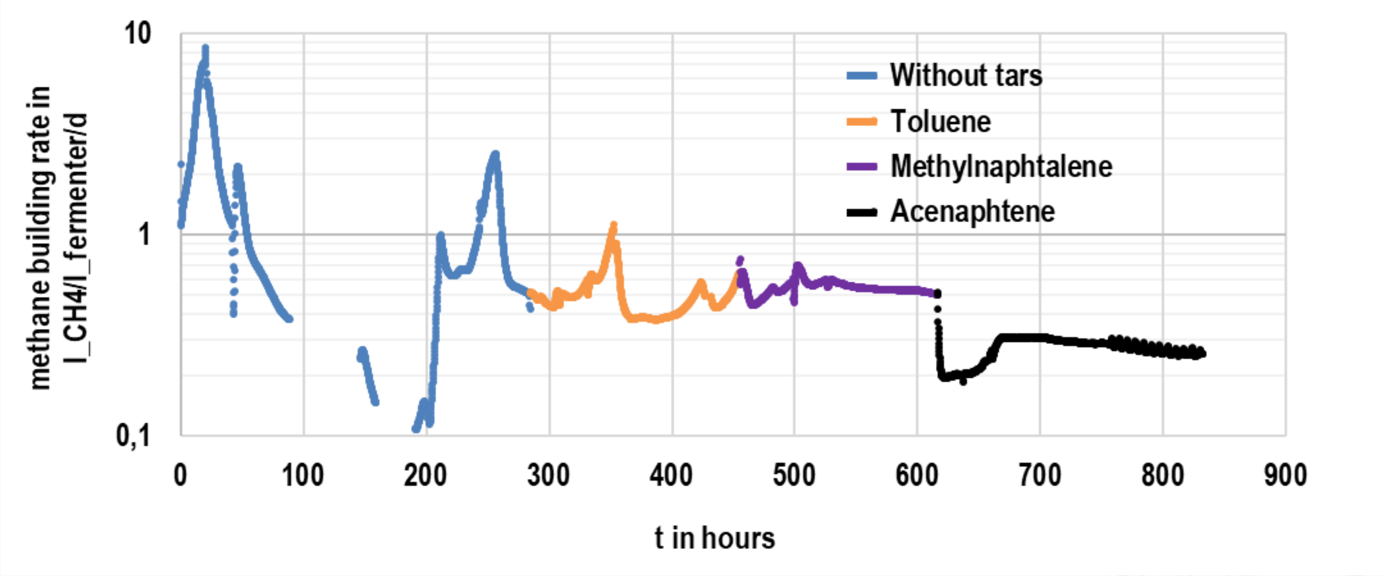
Results of adding tars



- Toluene and methylnaphthalene (daily dosage):
  - similar effect
  - High MBR peaks are stopped; stable MBR at low level, but:
  - No stalling of the culture
- Acenaphten (only one dosage):
  - Break-down of MBR within hours
  - MBR stabilizes at very low level after some time

tars are the main challenge with biological methanation of gasification syngas

Conclusion

Basics biological methanation
Facility setup
Experimental setup
Results
Conclusion

- A CSTR has been built
- Several components and impurities are added to synthetic feed gas:
  - CO:
    - CO is not a critical component
    - can be metabolized to CH_4
  - Gasification ash:
    - Ash dosage has no visible effect in CSTR
    - Problems with ashes in other fermenter types
  - Tars:
    - tars are the main challenge with biological methanation of gasification syngas
    - Different effects result from different tars
    - Probably tars have to be cleaned out of the syngas or:
    - Research and adaption of cultures has to be done