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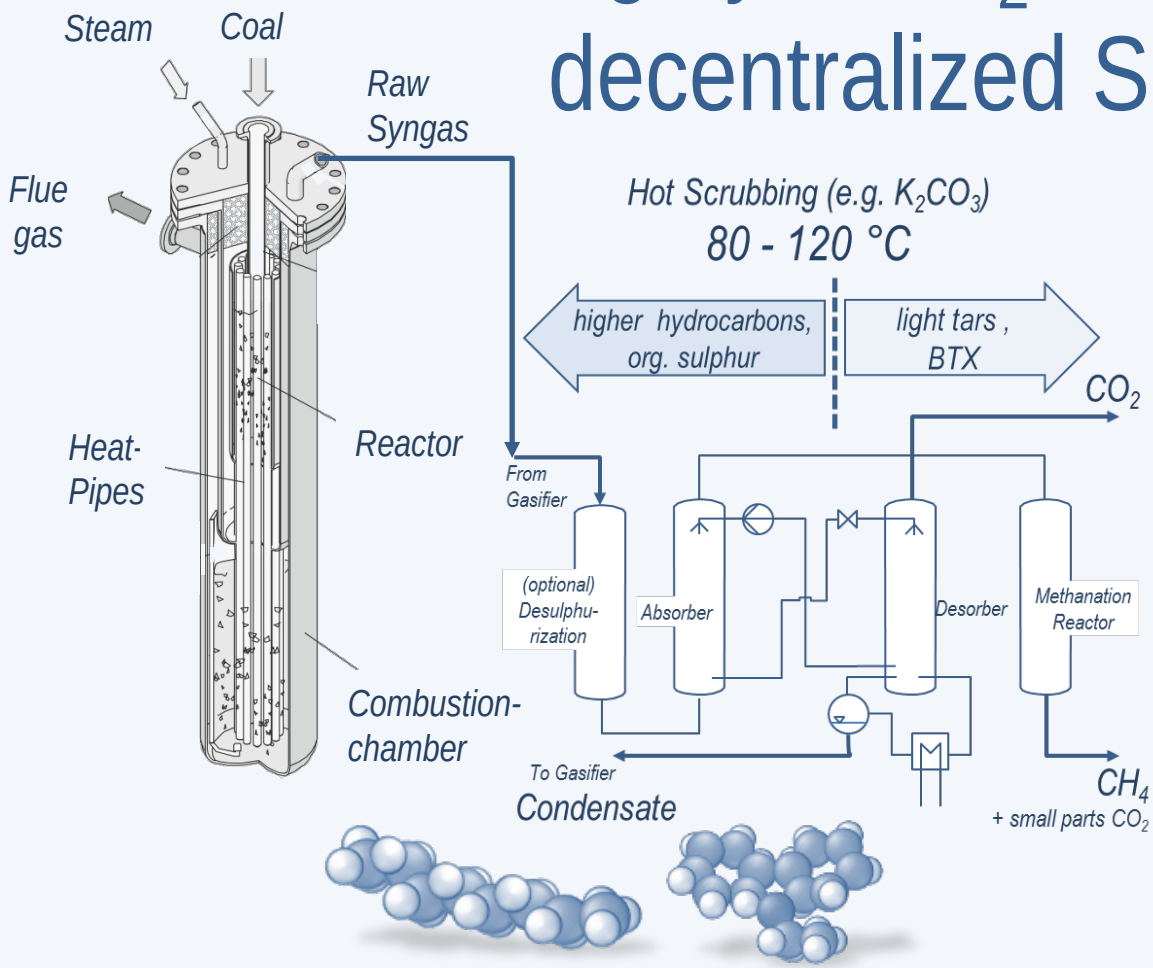
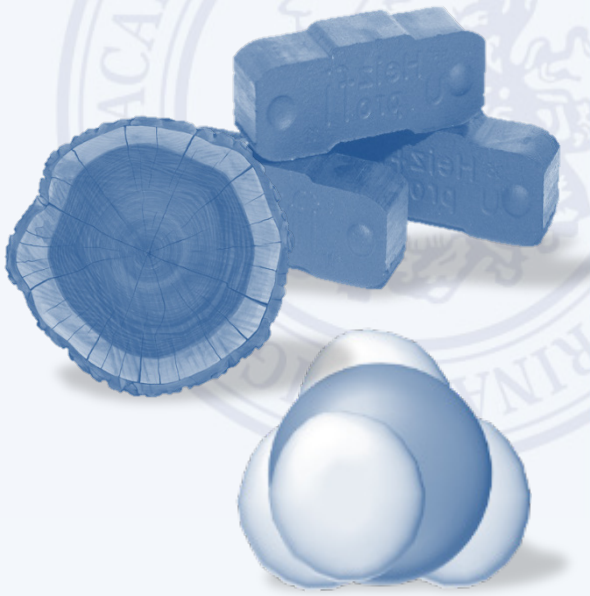
Allothermal gasification and integrated syngas cleaning by hot K_2CO_3 scrubbing for decentralized SNG production

Dipl.-Ing. Peter Treiber





Agenda

1. Motivation:

- CO2freeSNG2.0 – Coal-to-SNG with integrated syngas cleaning

2. Coal/Biomass-to-SNG

- Allothermal gasification and carbonate syngas scrubbing

3. EVT lab-scale test stands

- 5 kW gasifier and Benfield scrubber

4. Results Gasification

- Gasification
- Syngas cleaning

5. Conclusion

Motivation - CO2freeSNG2.0

CO2free SNG 2.0

Project goals

- Integrated **process optimization** and economic feasibility study of medium-scale SNG plants based on process **simulations**
- Extensive lab- and **bench-scale testing** of lignite gasification with integrated CO_2 removal and catalytic methanation (5 kW Process chain)
- **Demonstration** of the complete process chain with integrated technologies:
  - 100 kW EVT-Heatpipe Reformer
  - Scrubbing unit based on Benfield process
  - Methanation with conventional and new developed catalyst systems

Research Fund for Coal & Steel

The research project CO_2freeSNG2.0 (RFCR-CT-2013-00008) is funded by the Research Fund for Coal and Steel of the European Commission.

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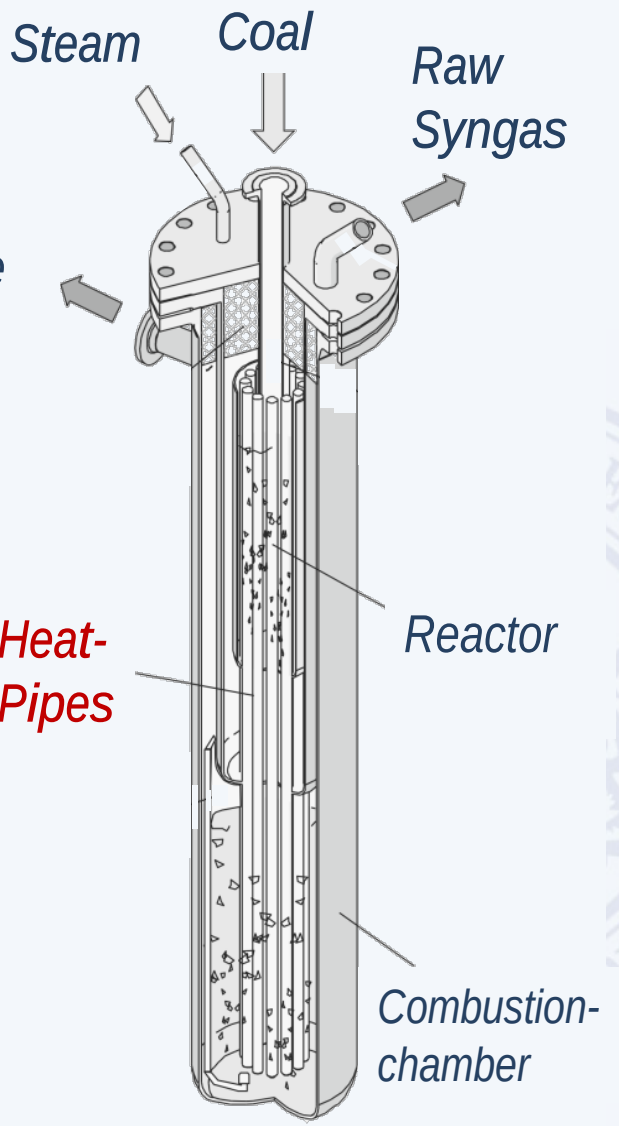
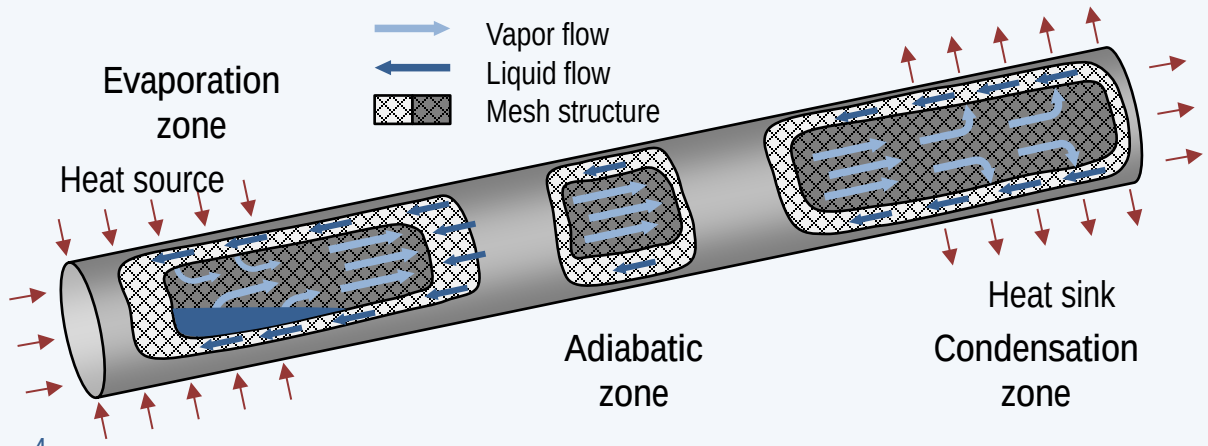
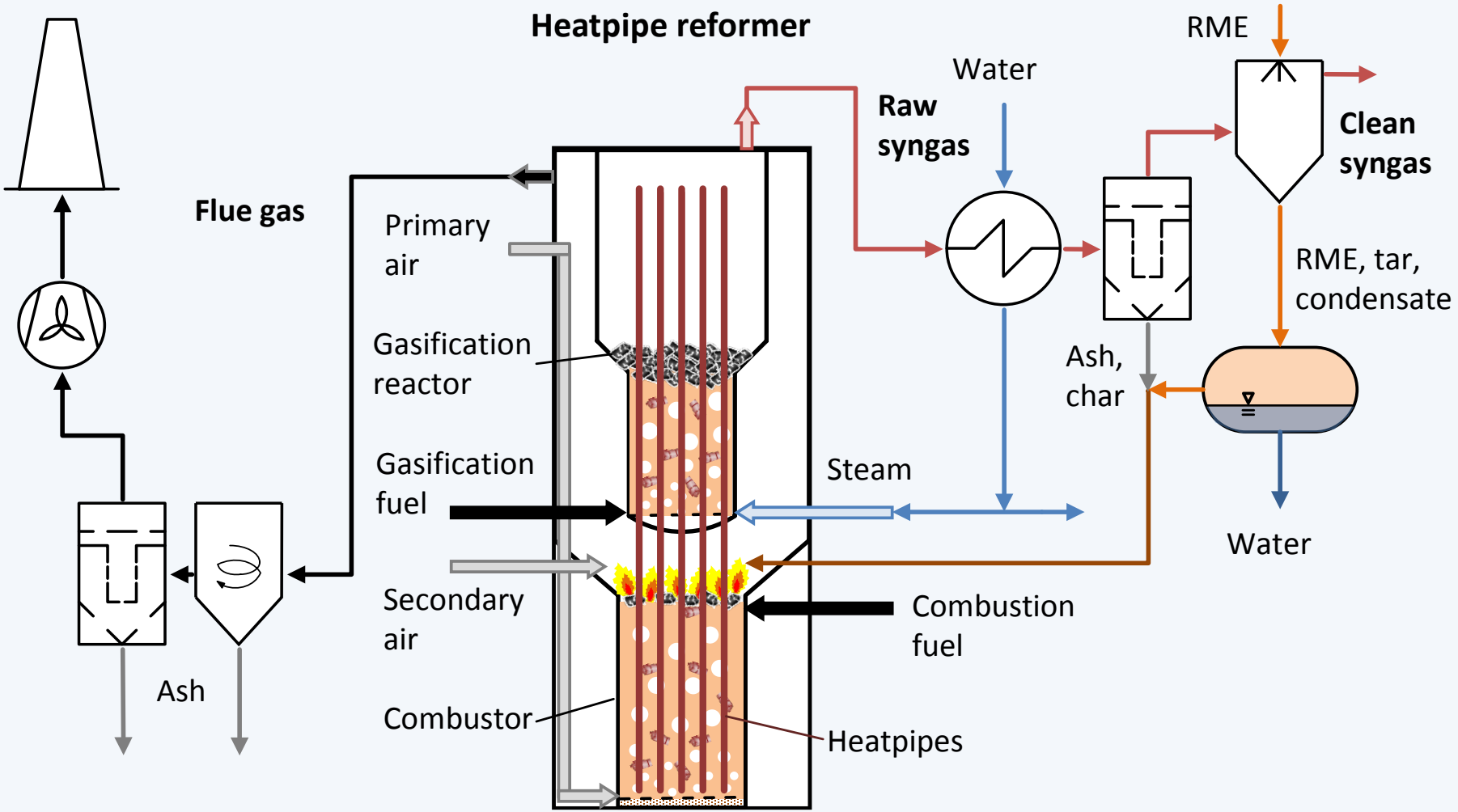
EVT – Heatpipe Reformer

- Allothermal steam gasification
- Dual fluidized bed reactor:
  - Atmospheric combustion
  - Pressurized gasification
  - Heat transfer by Heatpipes





EVT – Heatpipe Reformer



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Integrated Syngas Cleaning

Motivation

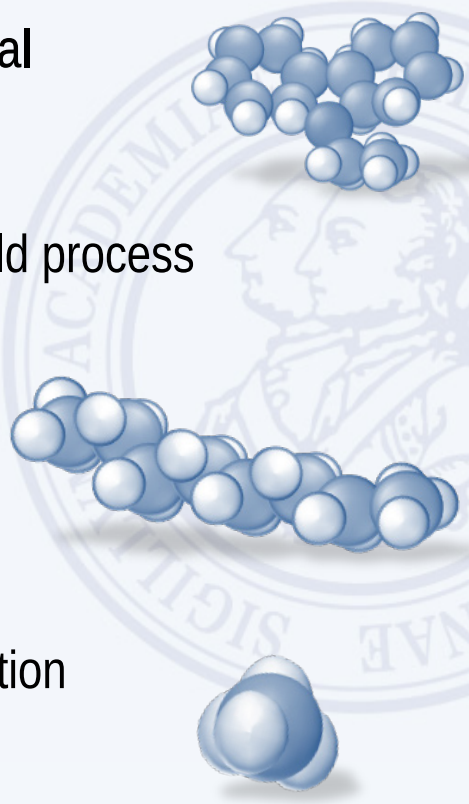
- Utilization of light hydrocarbons and tars (BTX) for methanation
- **Removal of heavy tars** to prevent coke formation
- Bulk **sulfur removal** necessary for catalyst life time
- Adjustment of the C/H/O-ratio by partial CO_2 **removal**

Approach

- Scrubbing at elevated temperature based on Benfield process
  - Condensation of heavier tars ✓
  - Bulk removal of sulfur components ✓
  - Removal of surplus CO_2 ✓

Application

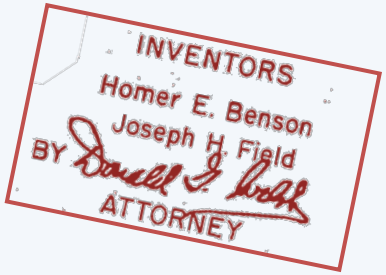
- Bulk syngas cleaning for decentralized SNG production in small and mid scale plants

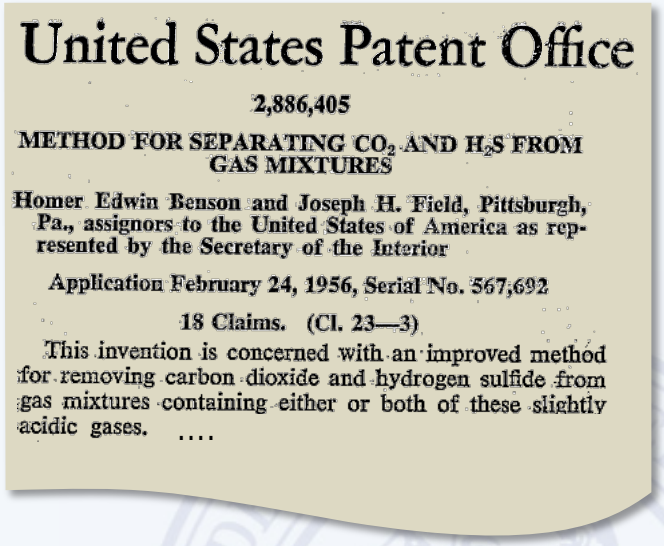


Carbonate Scrubbing – Benfield Process

Homer E. Benson

Joseph H. Field





United States Patent Office

2,886,405

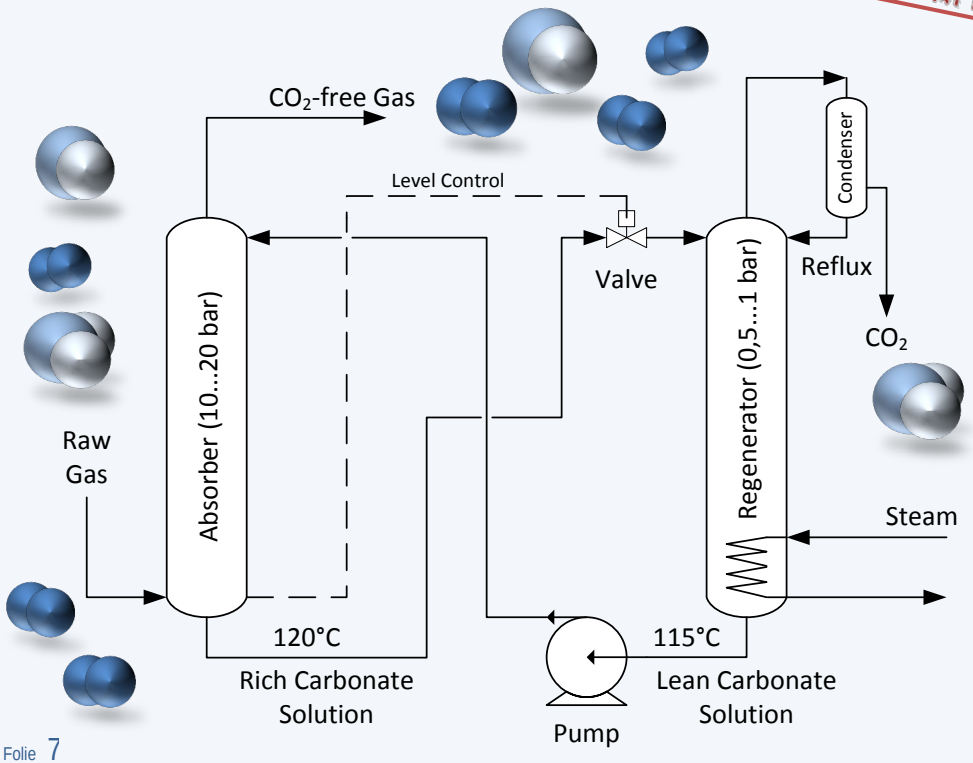
METHOD FOR SEPARATING CO_2 AND H_2S FROM GAS MIXTURES

Homer Edwin Benson and Joseph H. Field, Pittsburgh, Pa., assignors to the United States of America as represented by the Secretary of the Interior

Application February 24, 1956, Serial No. 567,692

18 Claims. (Cl. 23—3)

This invention is concerned with an improved method for removing carbon dioxide and hydrogen sulfide from gas mixtures containing either or both of these slightly acidic gases. ....



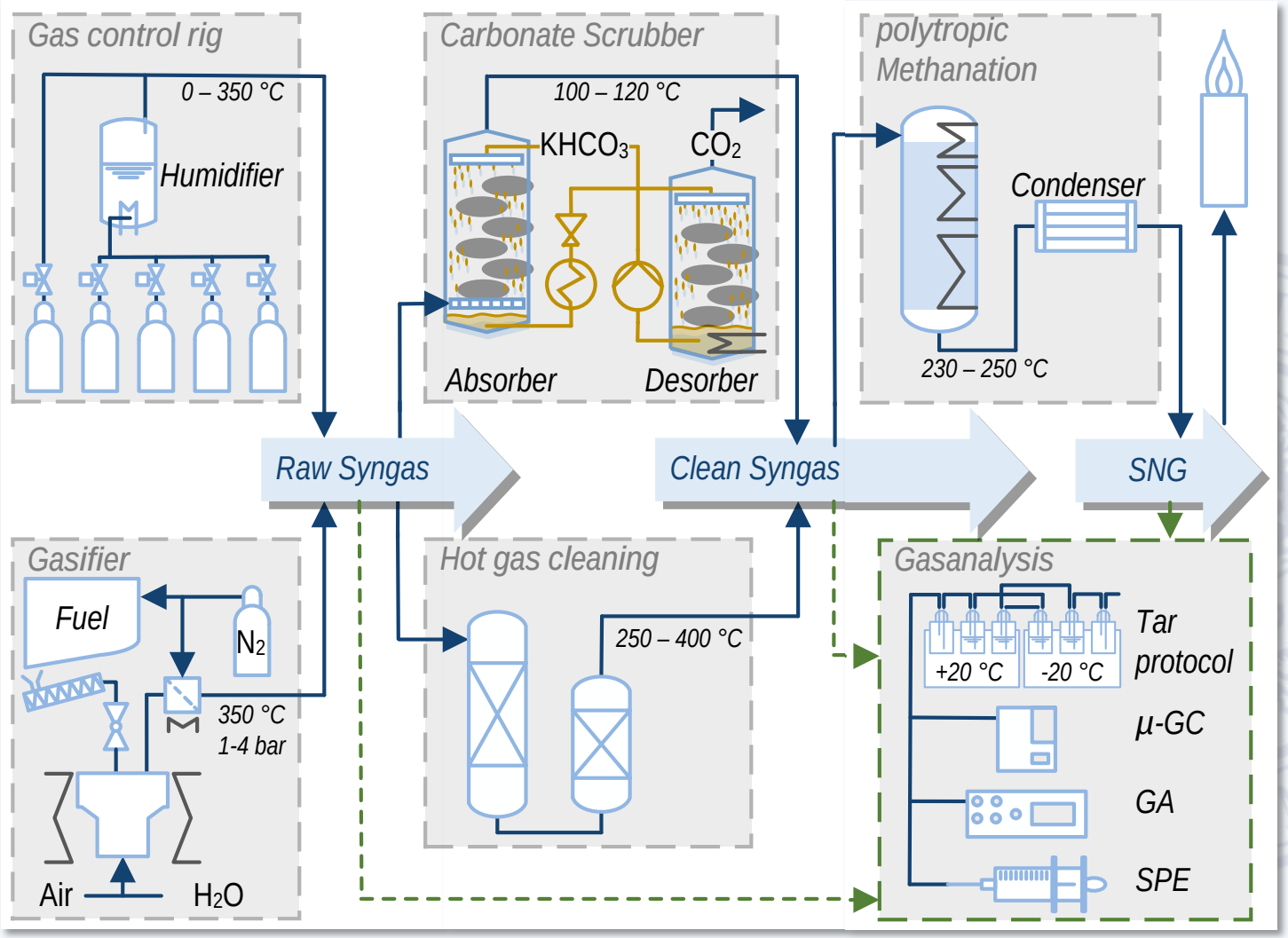
Basic data Carbonate scrubbing

- Increased solvent temperature
- No additional solvent cooling before absorber inlet
- Low reboiler duty (steam) necessary
- Stabile and non-toxic solvent

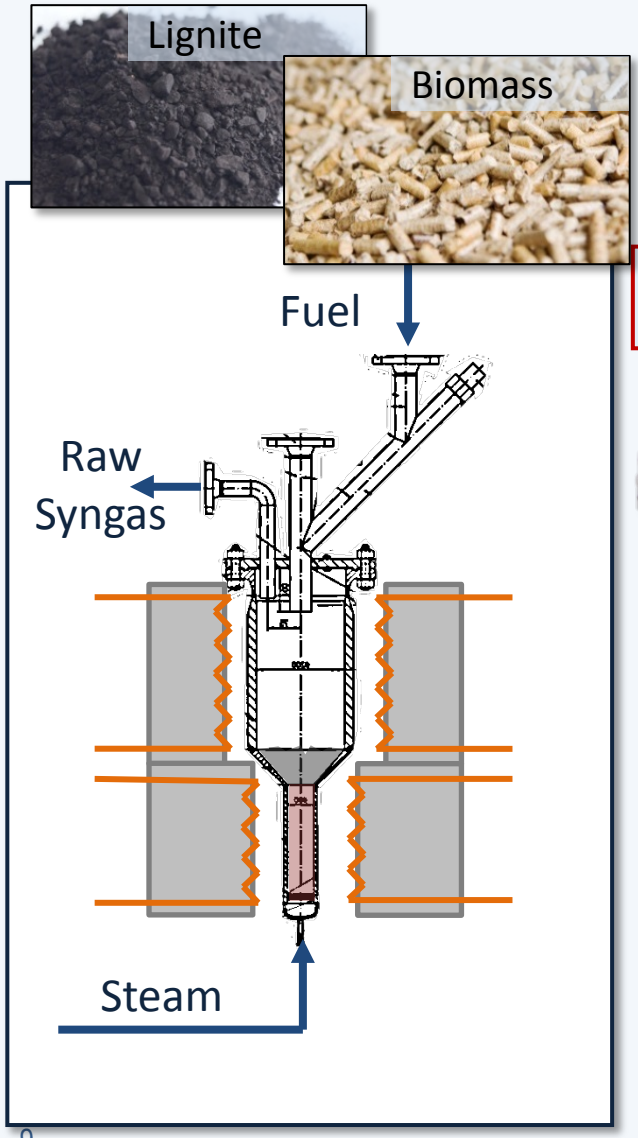
$$K_2CO_3 + CO_2 + H_2O \rightleftharpoons 2\,KHCO_3$$

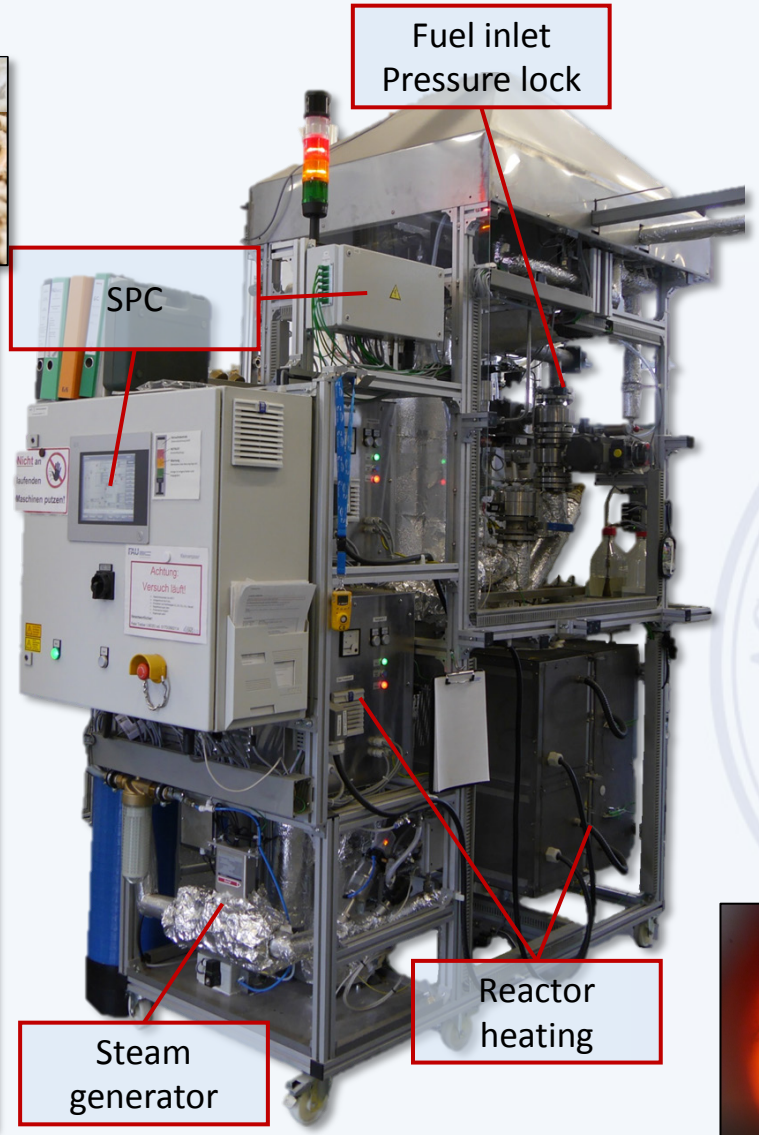
$$K_2CO_3 + H_2S \rightleftharpoons KHS + KHCO_3$$

SNG-Production – process chain 5 kW



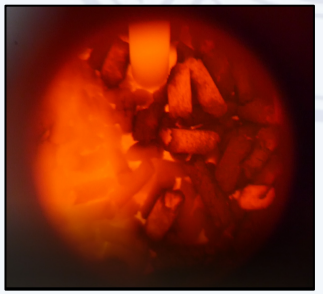
SNG-Production – 5 kW Gasifier



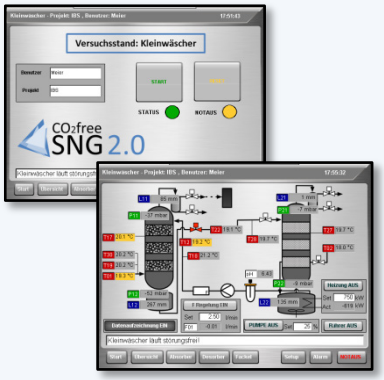


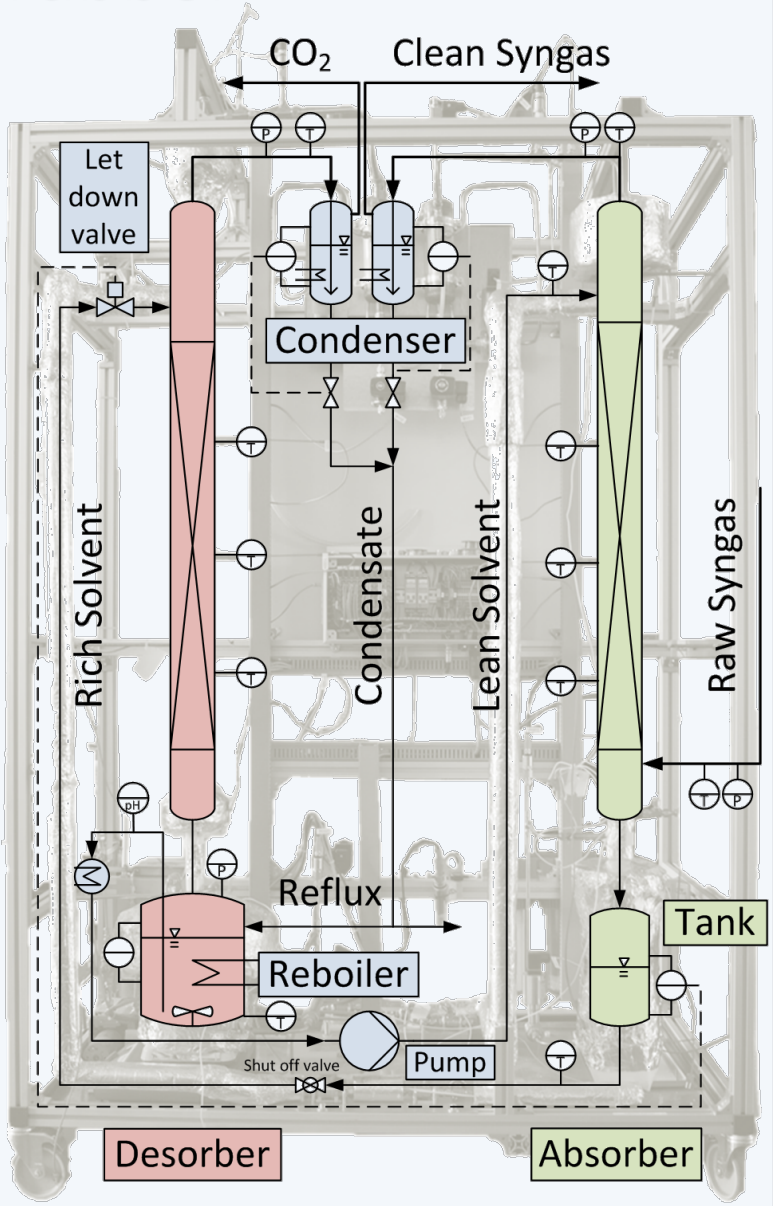
Technical Data

- Stationary fluidized bed
- Electrical reactor heating
- Allothermal steam gasification
- Pressure: up to 6 bar_a
- Gasification temperature: 800 – 900 °C
- Hot gas filter
- Inspection glas



SNG-Production – 5 kW Scrubber

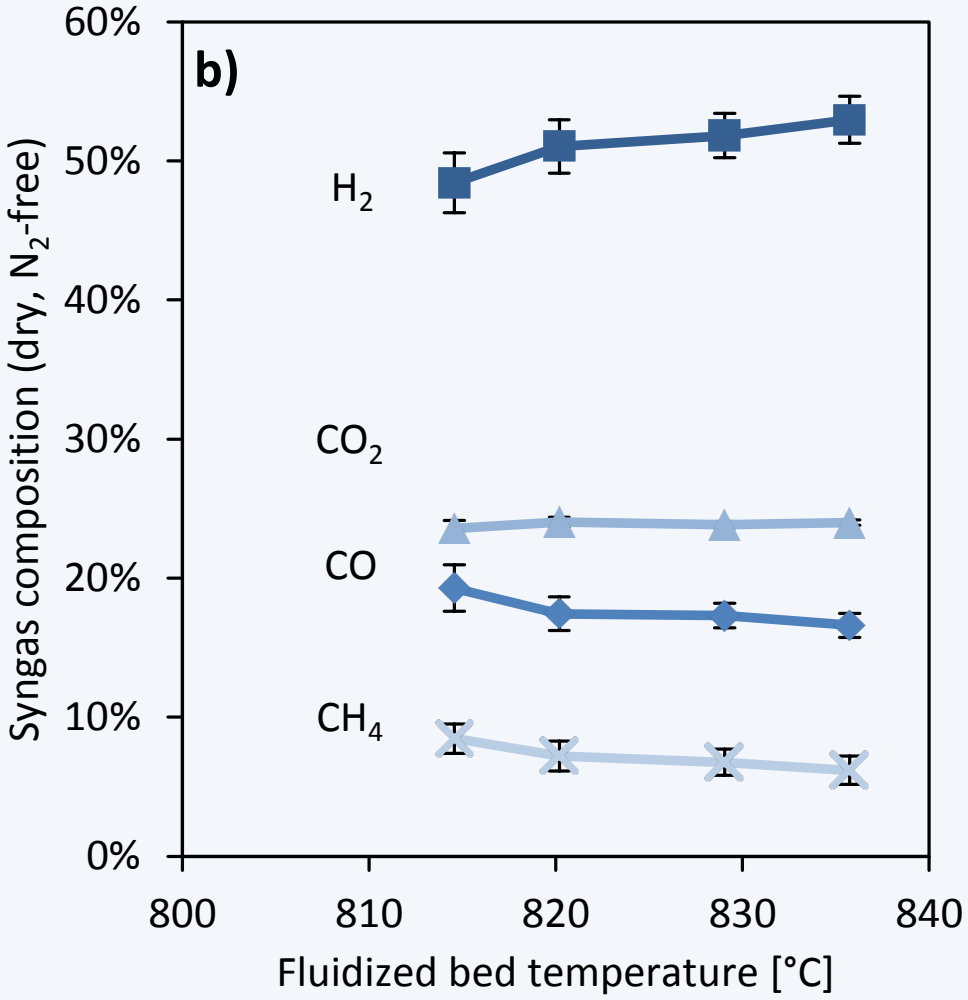




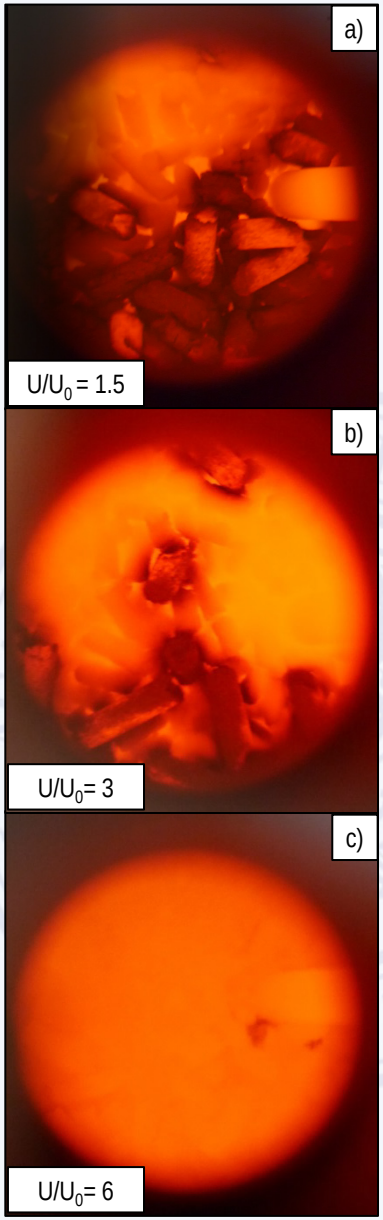
Technical Data

- $P = 5\ bar_a$, $T_{Solvent} = 100°C$, 30 wt.-% K_2CO_3
- Packings: Raschig Rings 6 mm VA

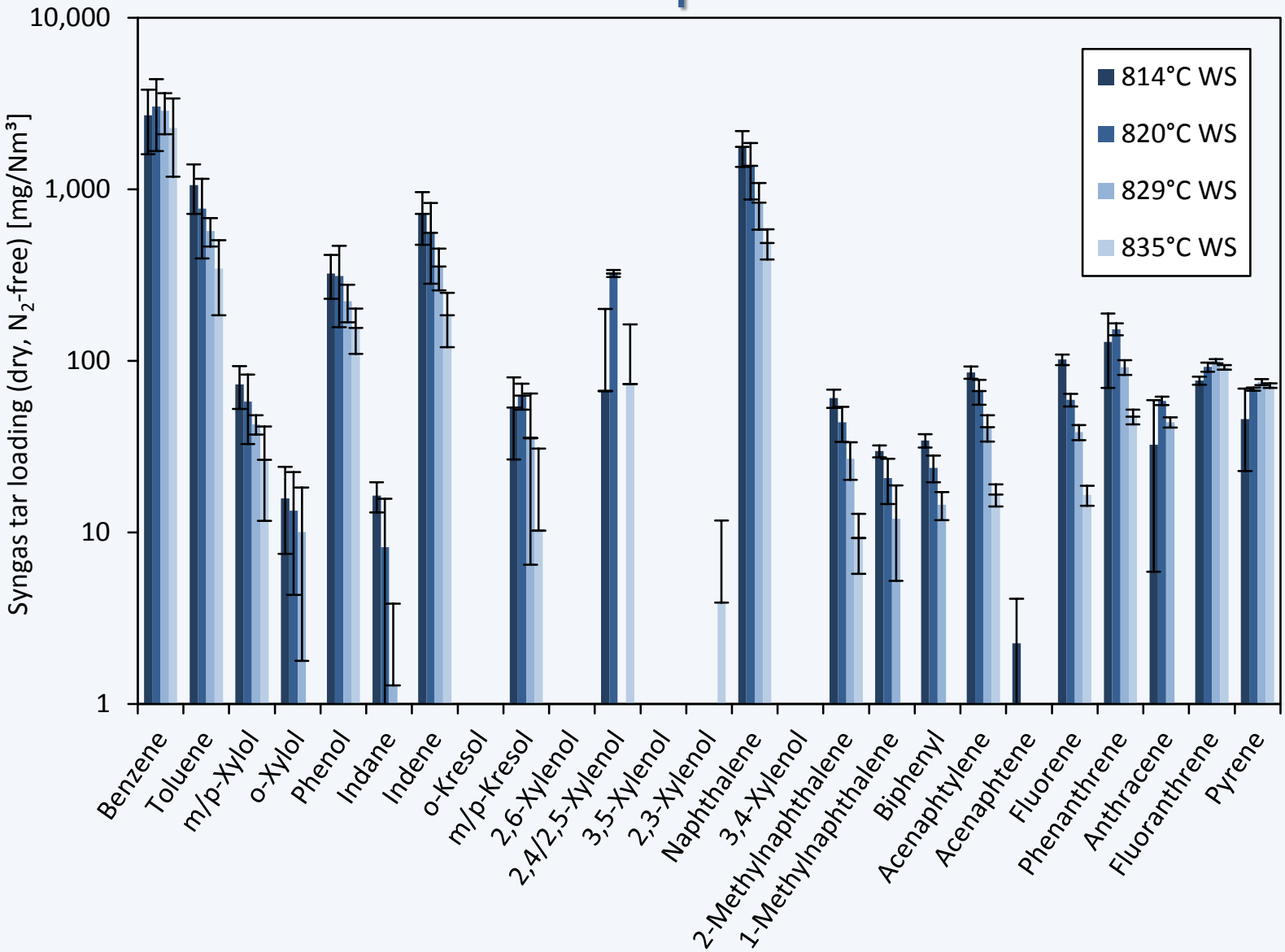
Results – Gasification – Temperature



Biomass gasification
$p = 1.3\ bar_a$
$\sigma = 12$

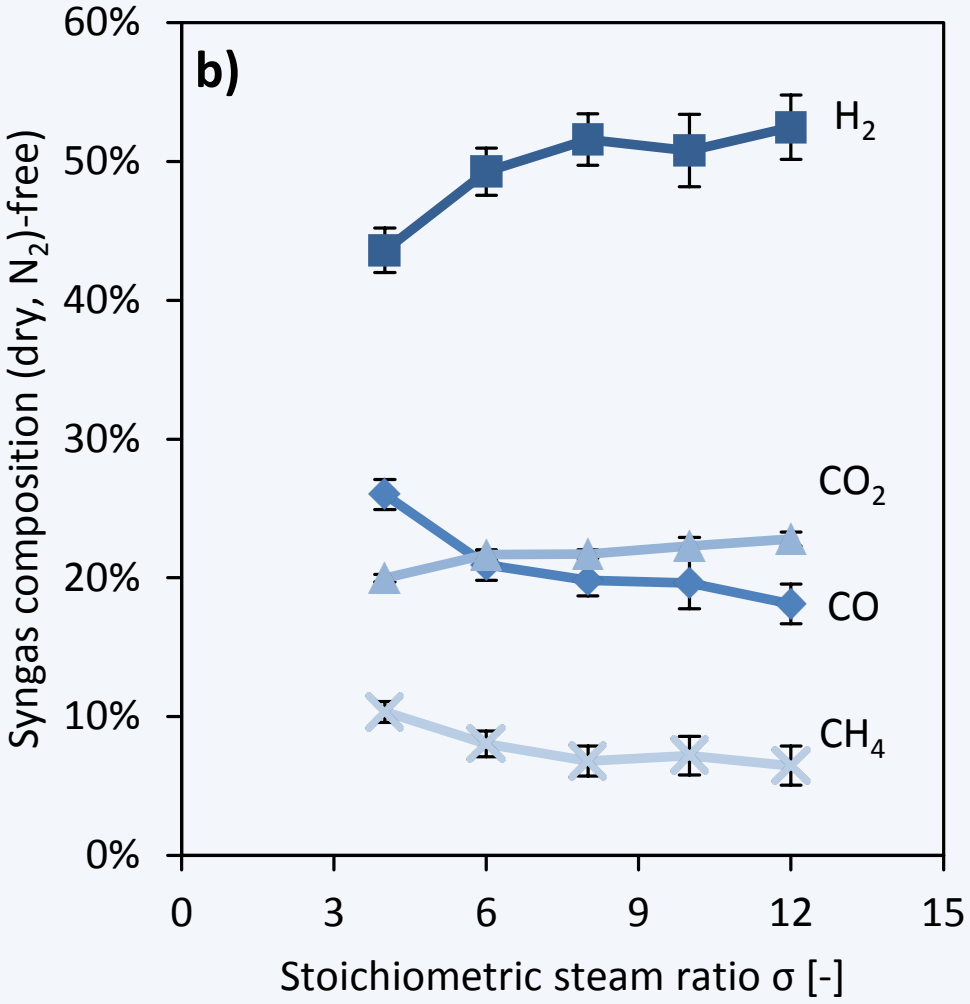


Results – Gasification – Temperature



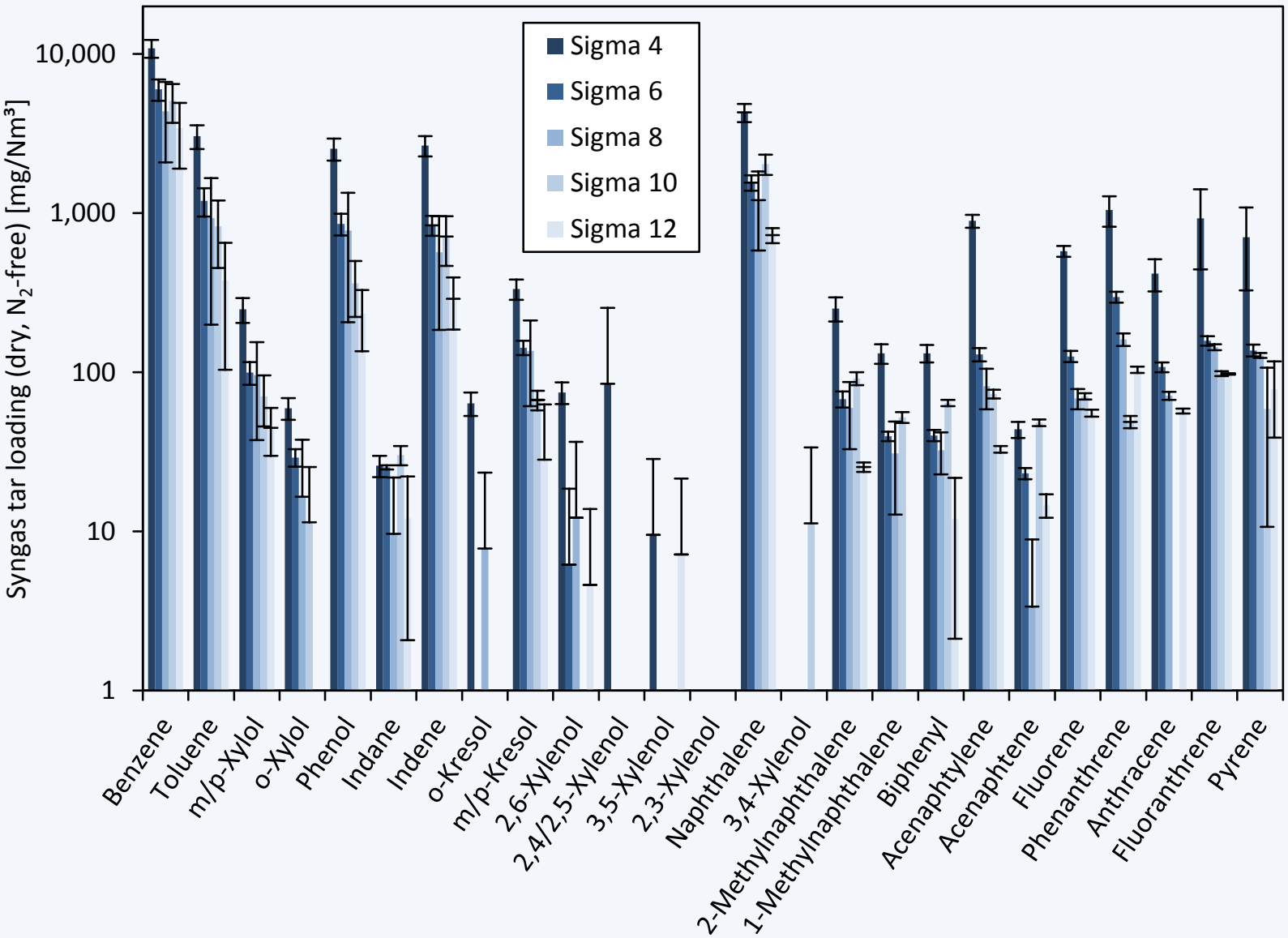
Biomass gasification
$p = 1.3\ bar_a$
$\sigma = 12$

Results – Gasification – Steam excess ratio



Biomass gasification
p = 1.3 bar_a
$\overline{T_{FB}}$ = 830 °C

Results – Gasification – Steam excess ratio



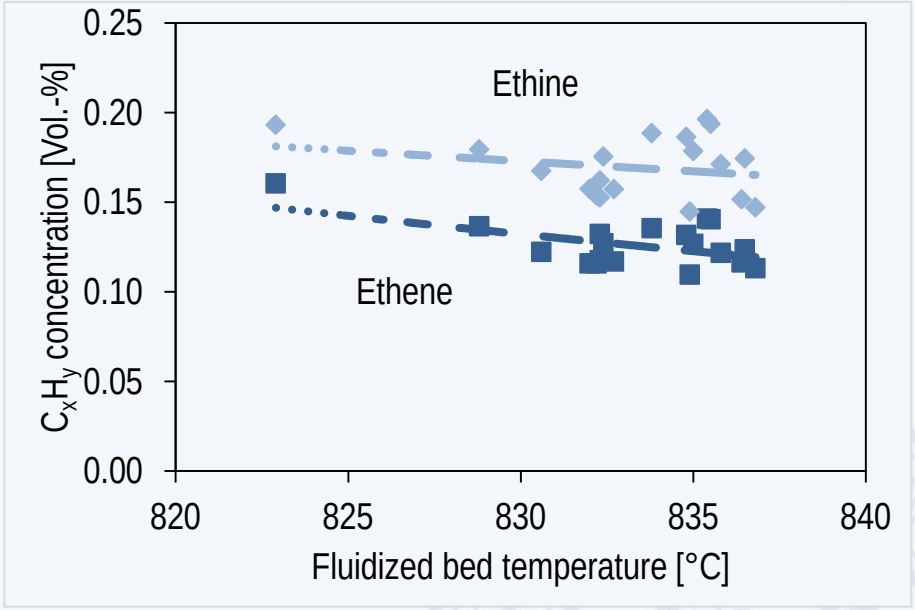
Biomass gasification
p = 1.3 bar_a
$\overline{T_{FB}}$ = 830 °C

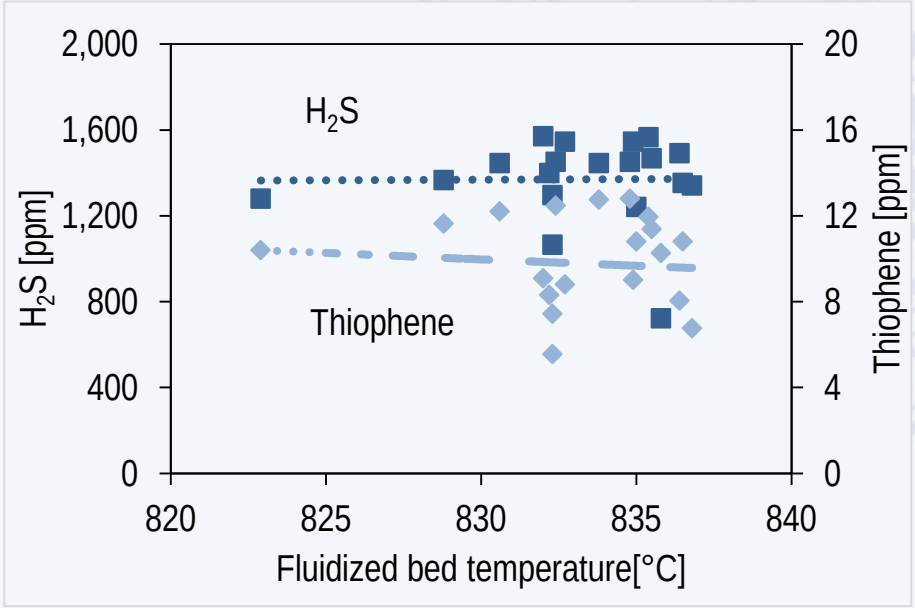
Results – Gasification

Light Hydrocarbons and Sulfur

- Overall tar reduction with rising gasification temperature
- At lower gasification temperatures shift towards aromates
- Ethene and Ethine decrease with rising gasification temperature
- Sulfur compounds barely affected by fluidized bed temperature
  - H_2S
  - Thiophene

$p = 5{,}2\ bar_a$, $\sigma = 3{,}26$





Results – Scrubber

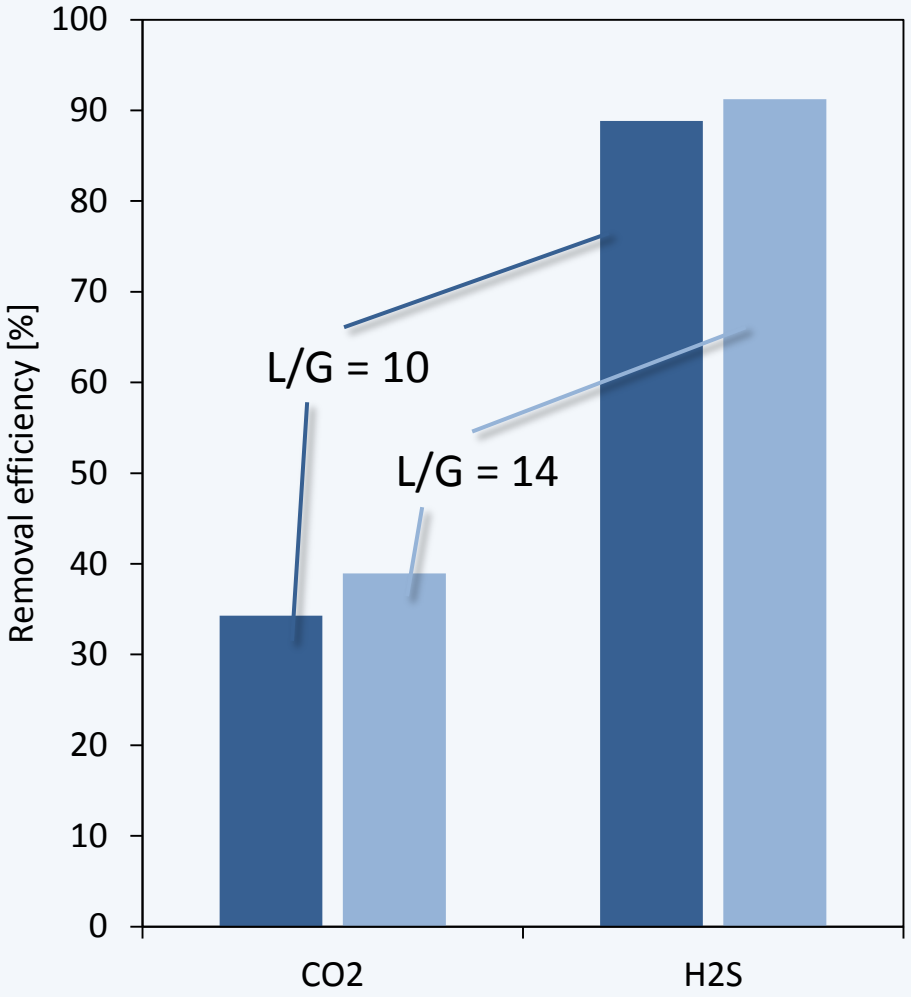
Removal efficiency

$$\eta_{CO2} = \frac{(x_{CO2,raw} - x_{CO2,clean})}{(x_{CO2,raw} \times (1 - x_{CO2,clean})}$$

$$\eta_{H2S} = \frac{(x_{H2S,raw} - x_{H2S,clean})}{(x_{H2S,raw} \times (1 - x_{H2S,clean})}$$

Liquid-to-Gas ratio

$$\frac{L}{G} = \frac{\dot{m}_{Solvent}}{\dot{m}_{Syngas}}$$



Simulation vs. bench scale tests

- Simulation of 90% CO_2 removal efficiency @ L/G 19 proofed only up to 65% in bench scale tests due to heat losses and edge effects → higher efficiency reached in pre-pilot scale

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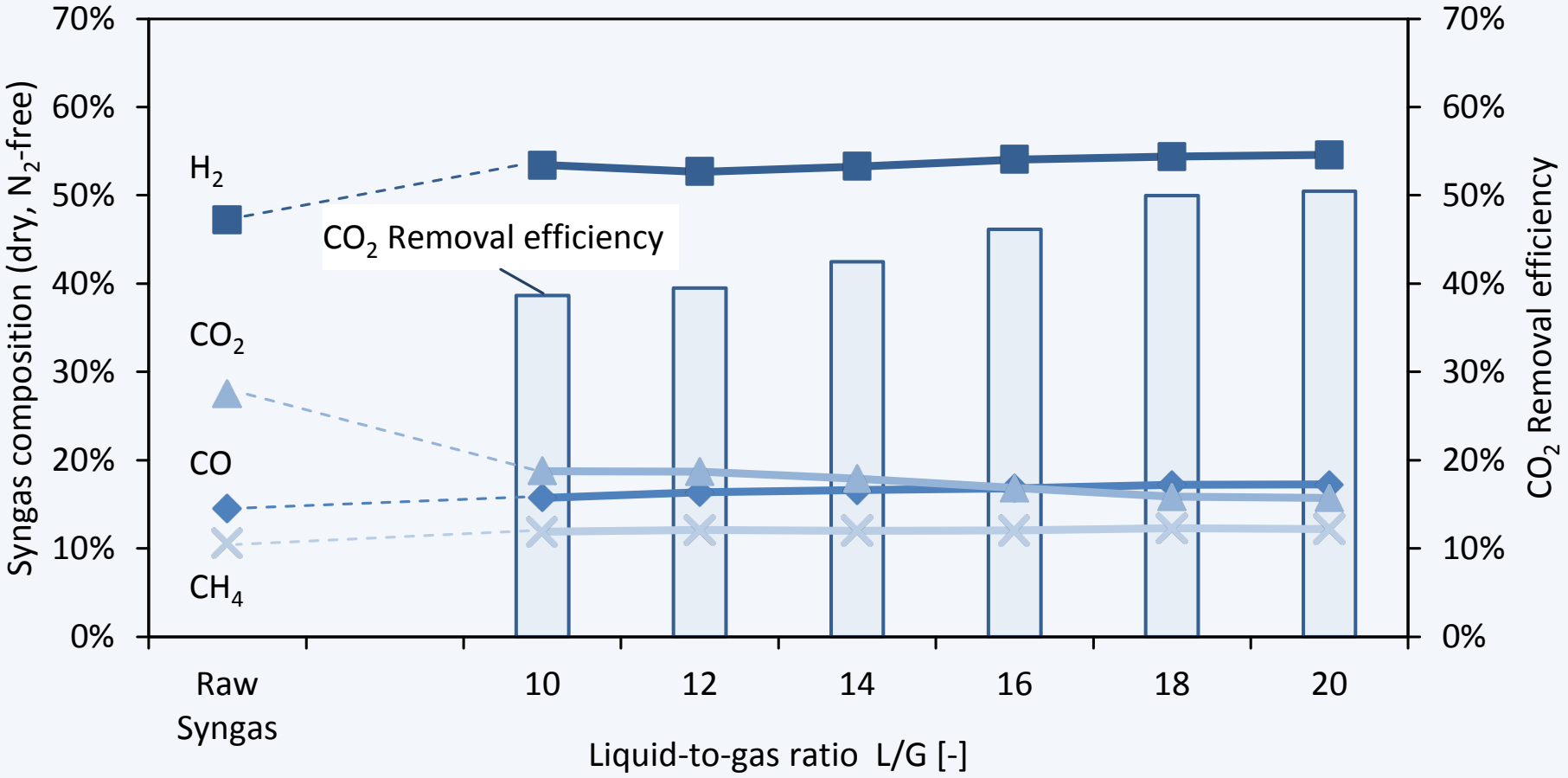
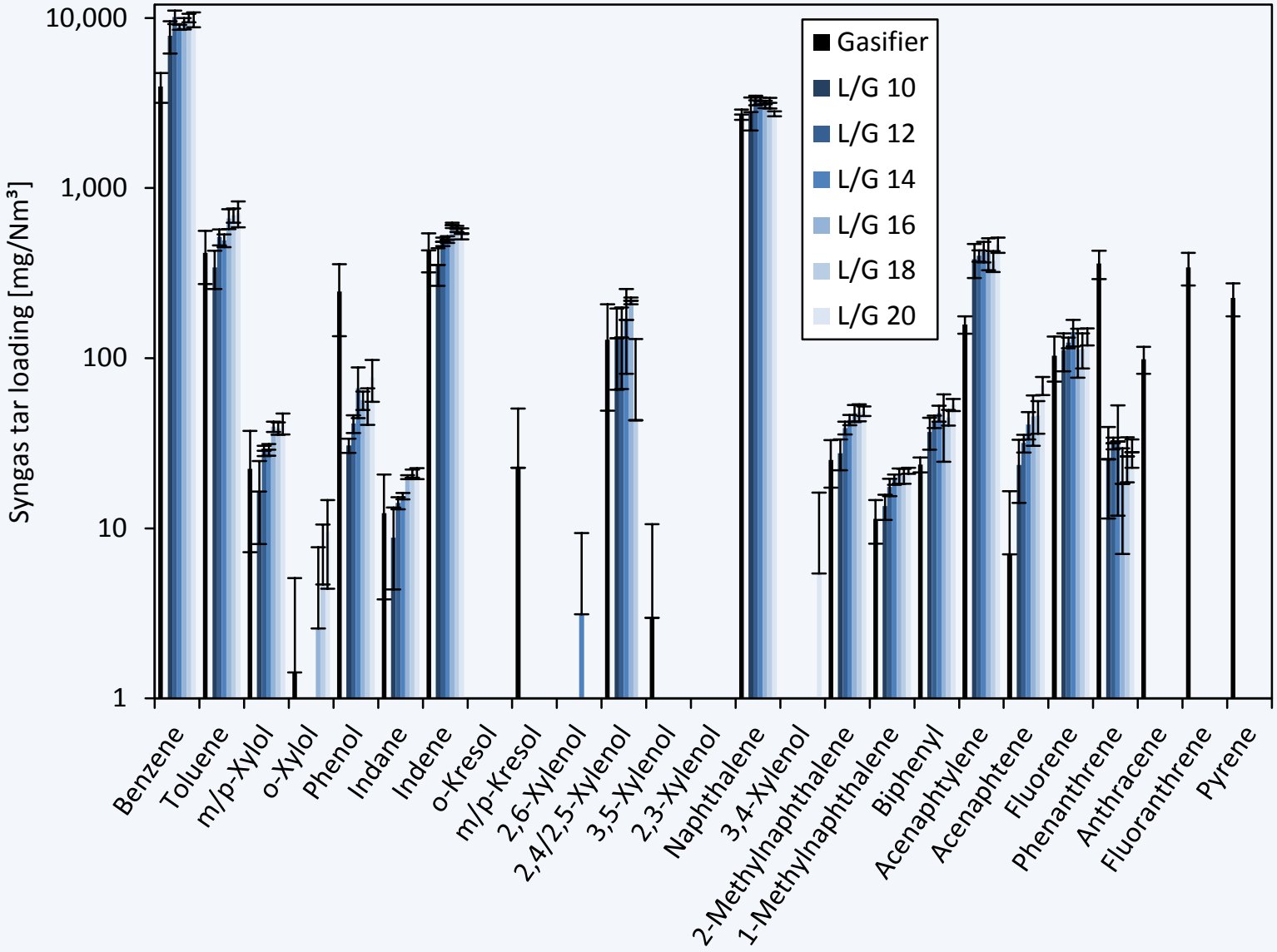
Results – Scrubber – L/G-ratio



Results – Scrubber – L/G-ratio



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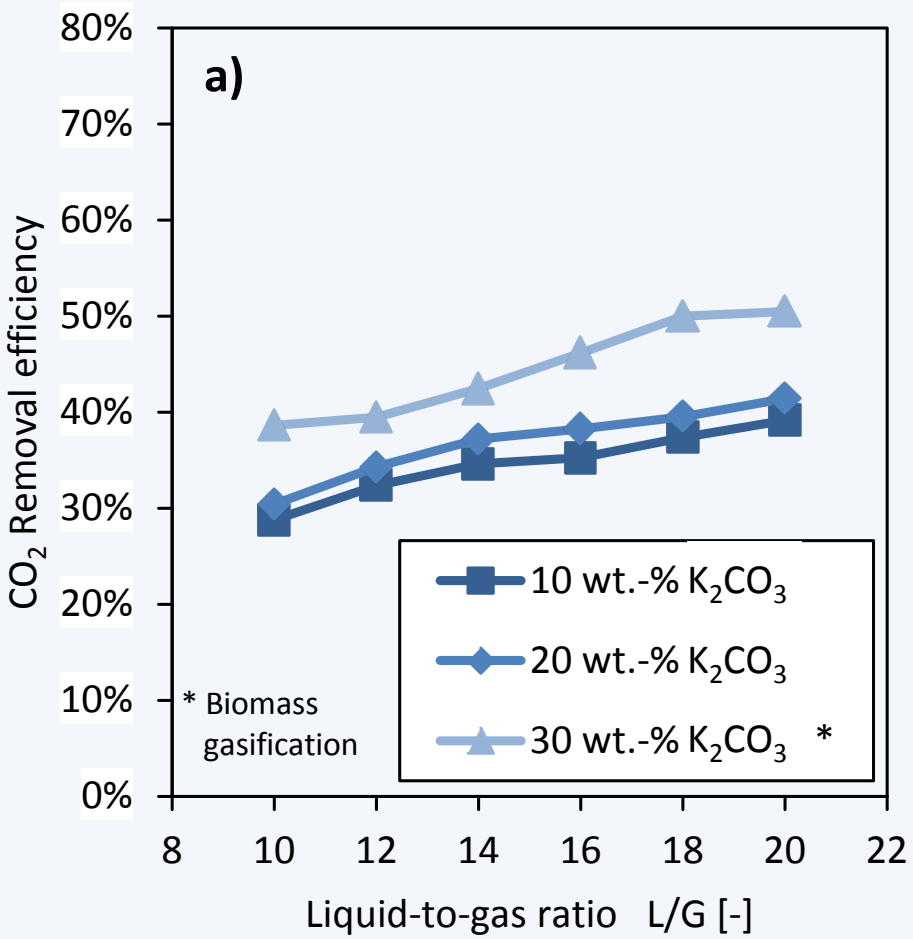
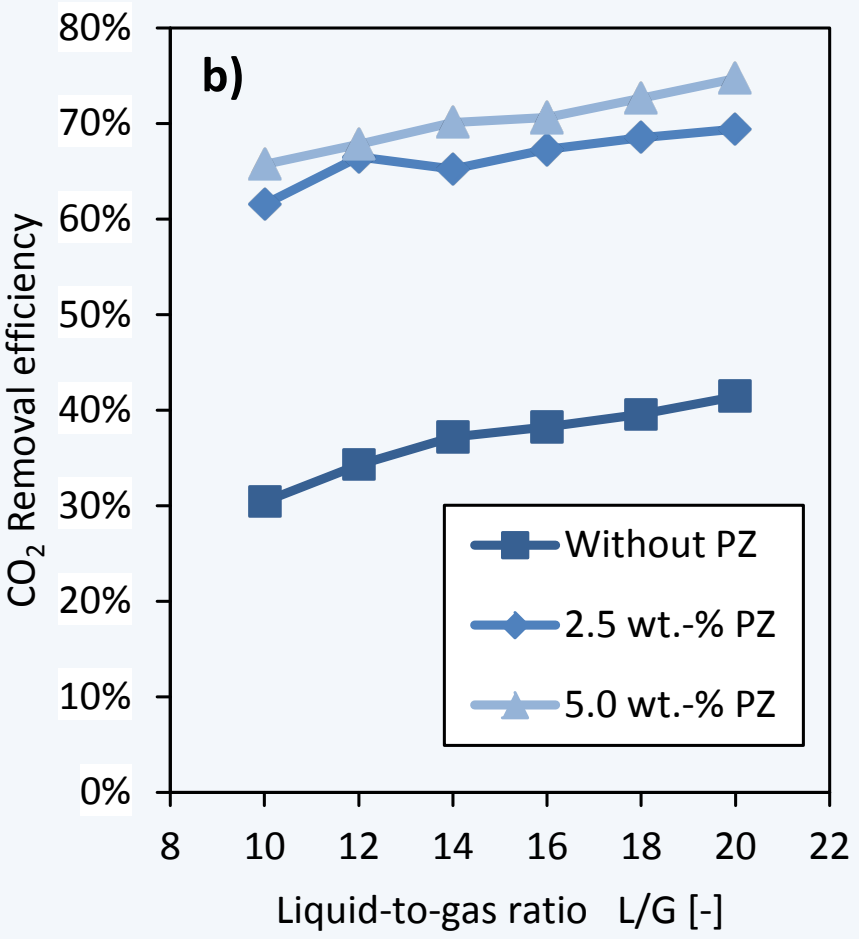
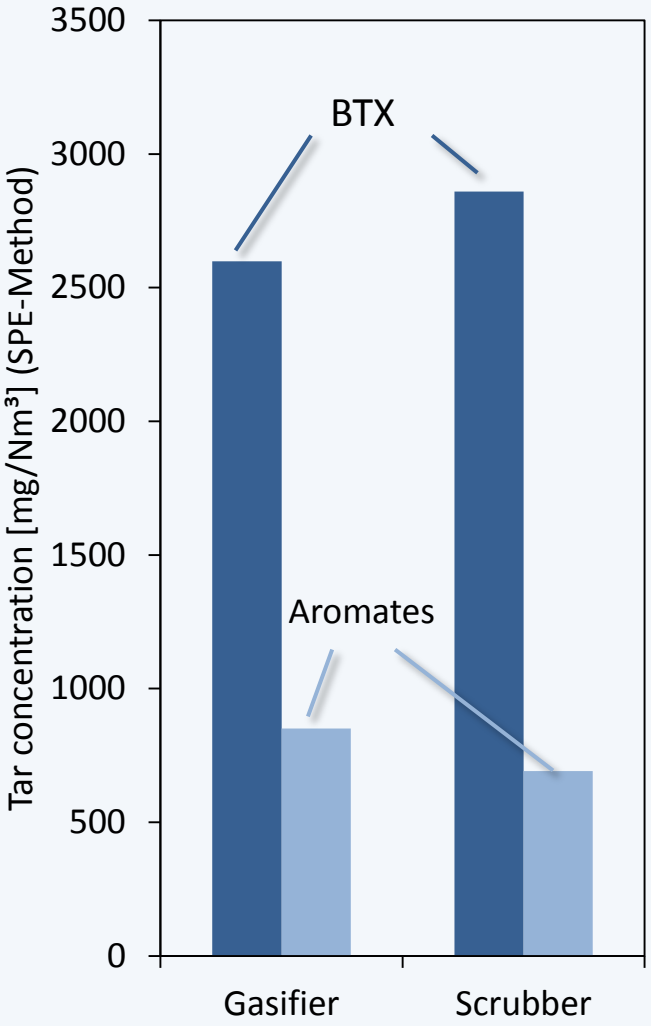
Results – Scrubber – Solvent





Results – Scrubber



Tar removal

- Reduced syngas vol.-flow due to CO_2 removal
- Higher BTX concentration after scrubber but
- Less aromates after scrubber
- Close to total removal of heavier hydrocarbons (T_B > 350 °C)

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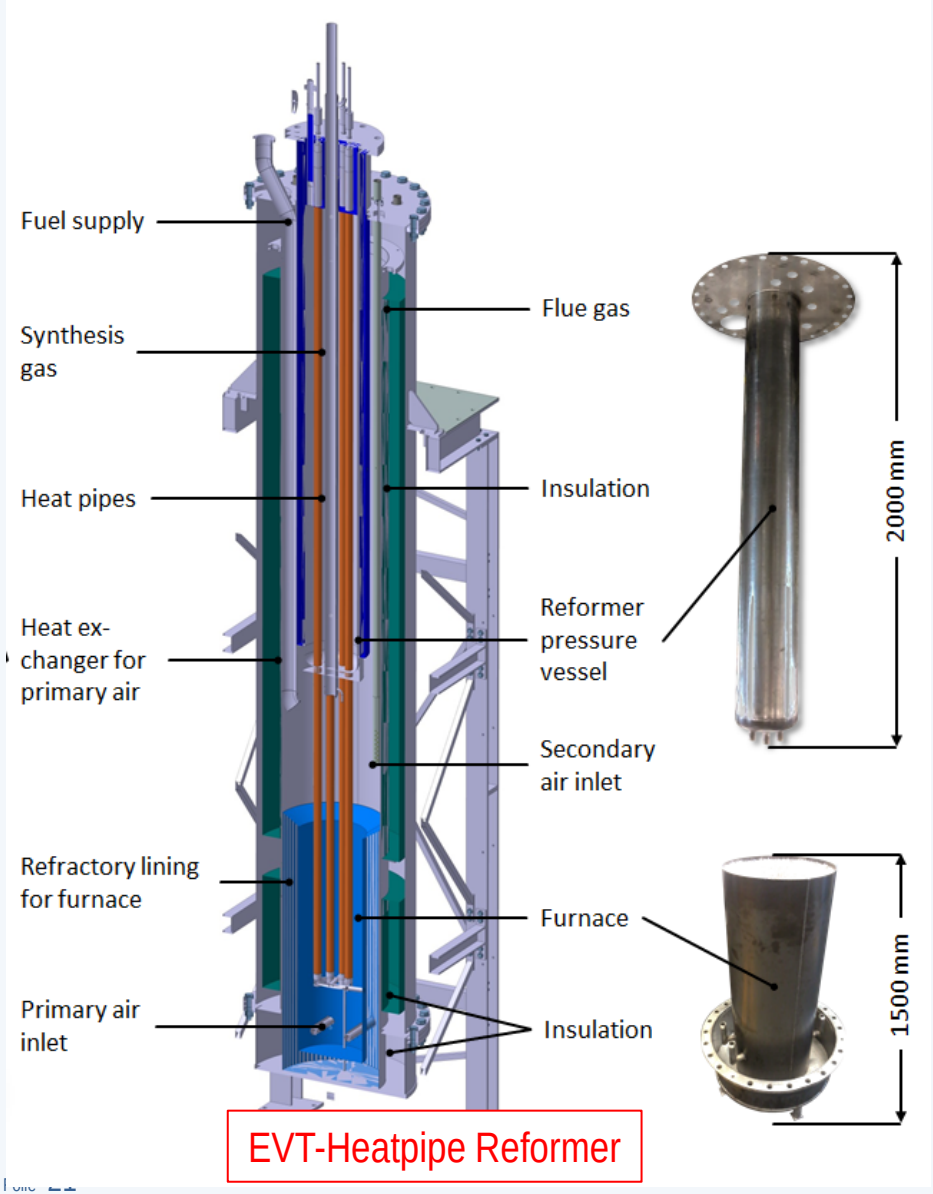
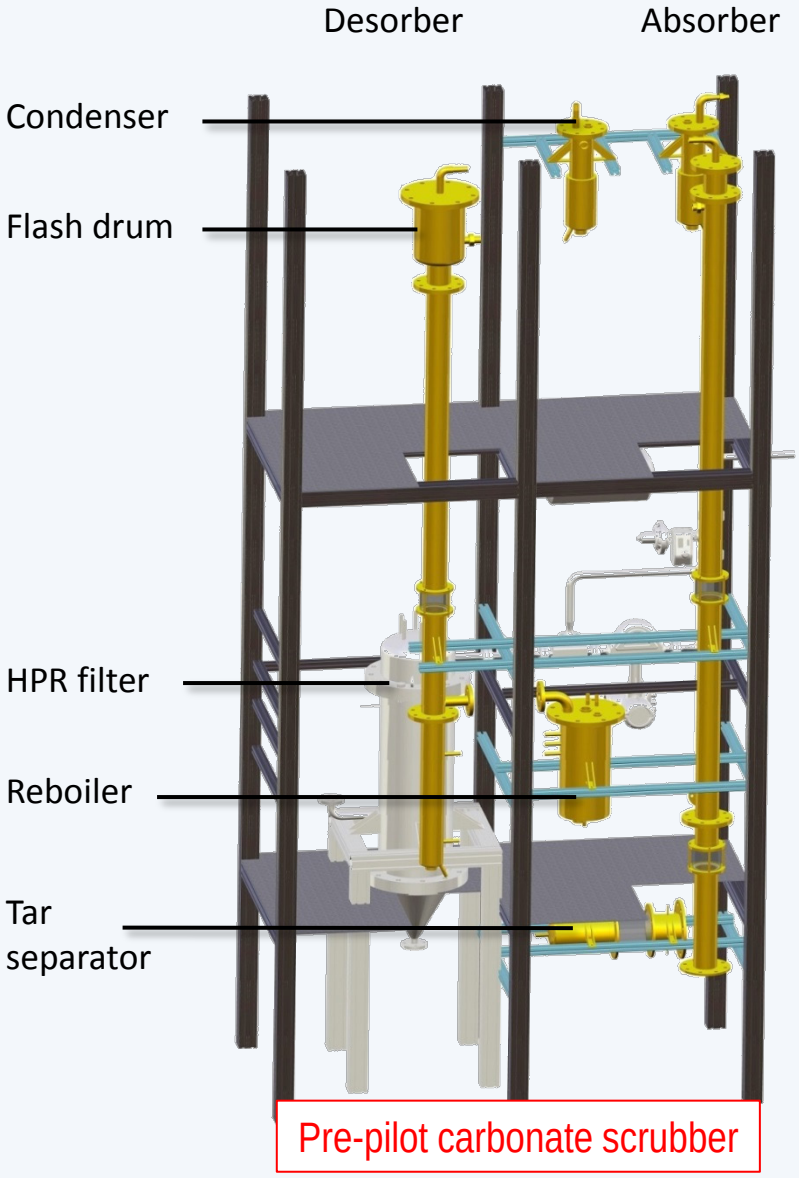
100 kW Process chain



EVT-Heatpipe Reformer



Pre-pilot carbonate scrubber

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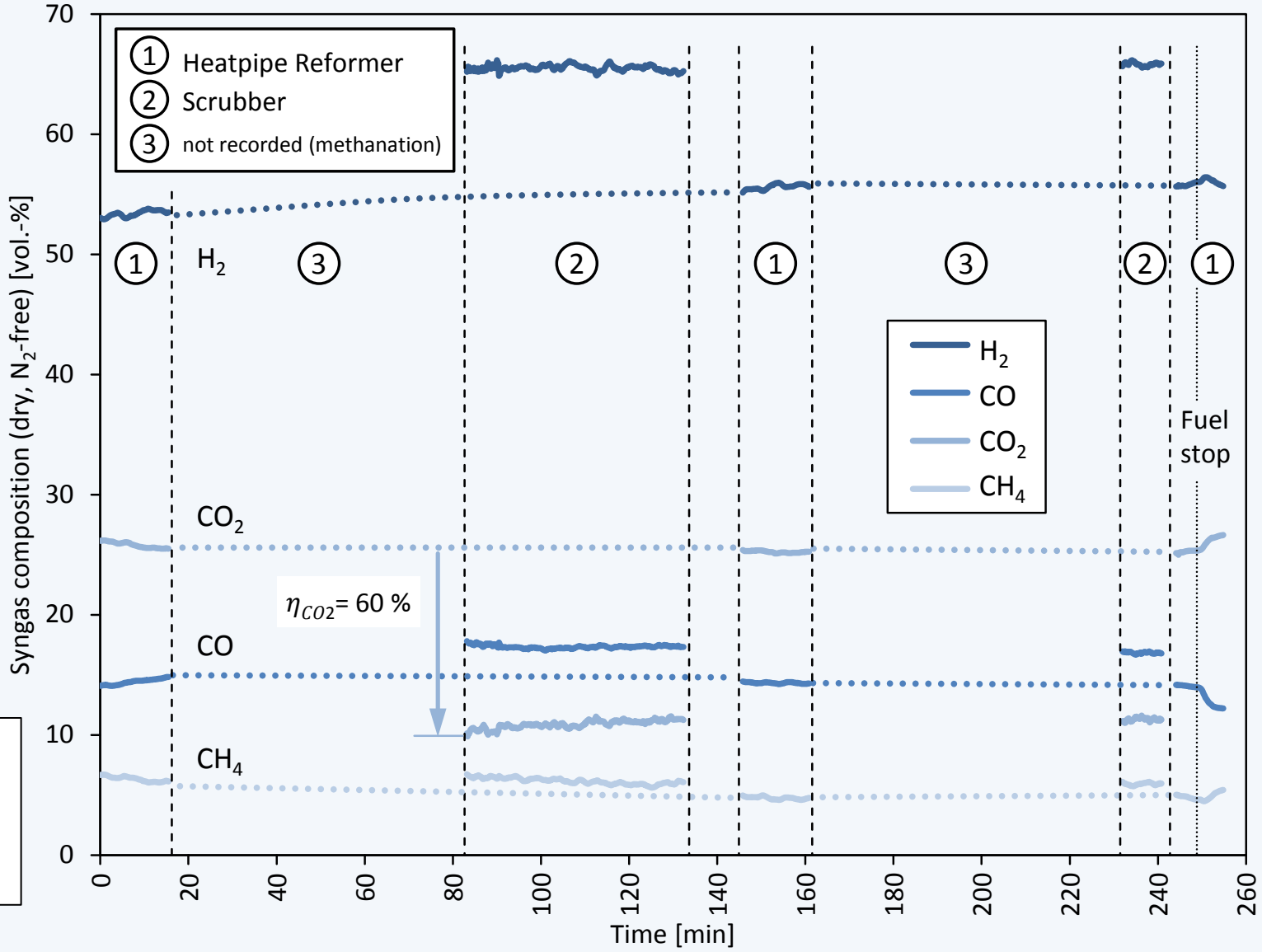
100 kW Process chain – Demonstration



Lignite gasification
$p_{gasifier}$ = 4,0 bar_a
$p_{absorber}$ = 3,8 bar_a
$T_{Syngas, clean}$ = 120 °C

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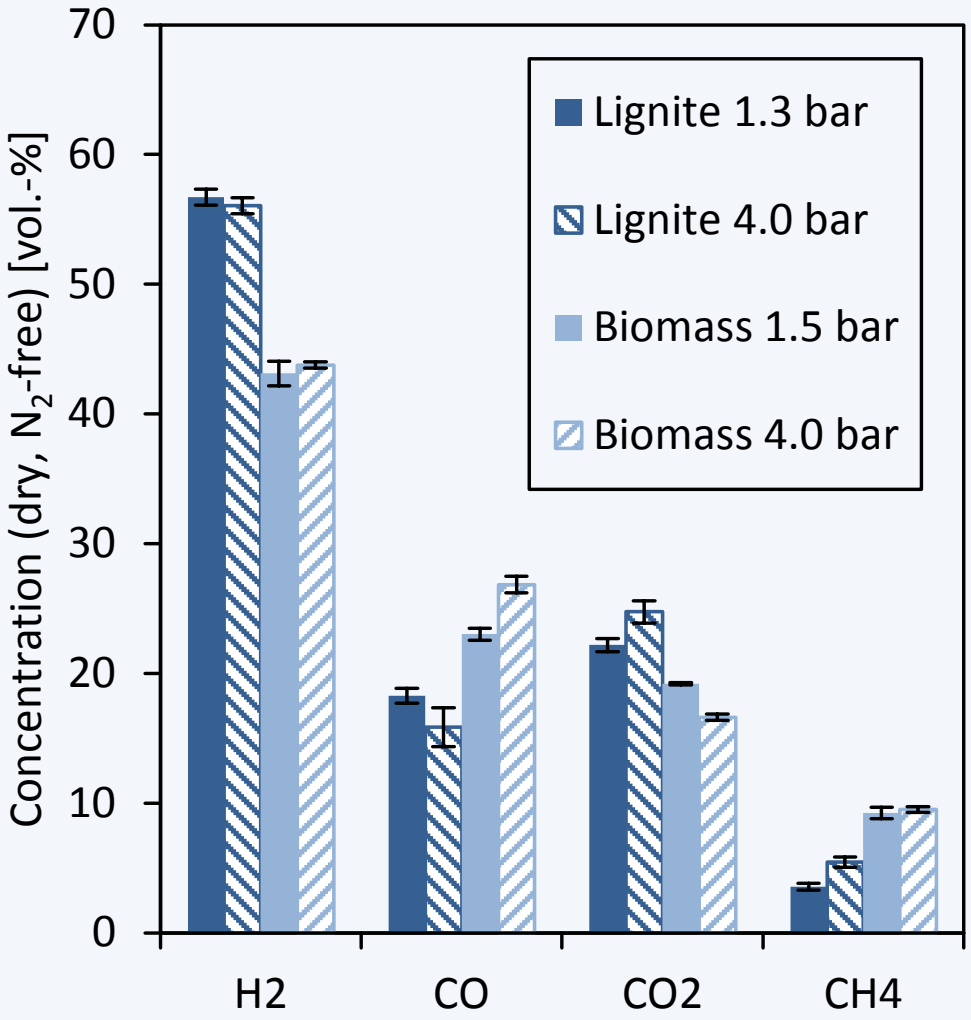
100 kW Process chain – Demonstration



Demonstration October 2016

pre-pilot scrubber at FAU

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Conclusion

CO2freeSNG2.0

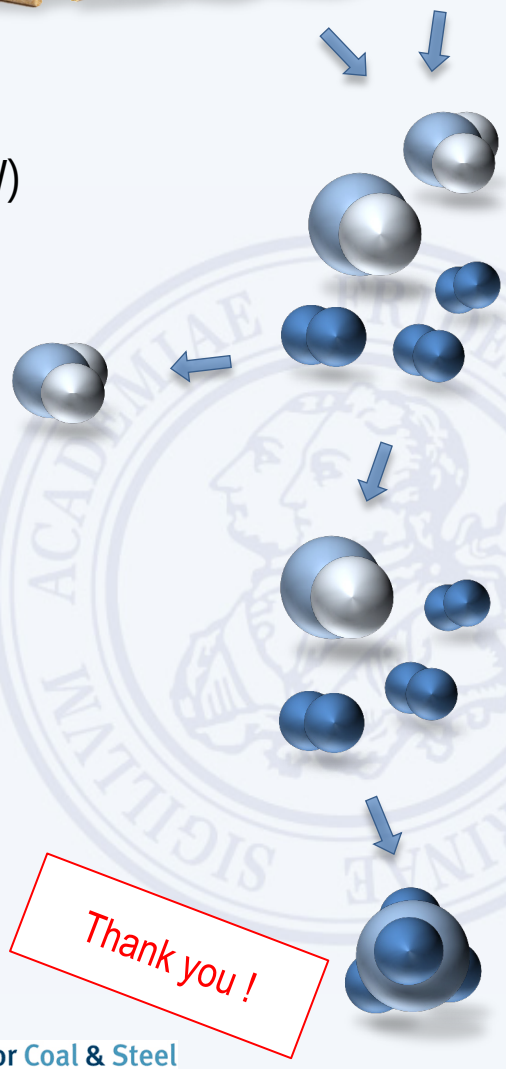
- Decentralized SNG-Production from coal or biomass with integrated syngas cleaning and CO_2-removal
- Bench scale testing: Gasifier, Scrubber, Methanation (5 kW)
- Demonstration of the pre-pilot scale process chain
  - Heatpipe Reformer(100 kW) + Scrubber

Allothermal steam gasification

- Steam surplus variation to support methanation
- Tar load and composition in focus of investigation

Integrated Syngas Cleaning

- Syngas scrubbing at elevated temperatures based on the Benfield process as bulk cleaning process
  - Heavy tar components (Condensation)
  - Surplus CO_2 und sulfur compounds removal
- Utilization of light hydrocarbons in Methanation



Thank you !

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