University of Stuttgart
Institute of Combustion and Power Plant Technology
Prof. Dr. techn. G. Scheffknecht

Sorption Enhanced Gasification:

Process validation and investigations on the syngas composition in a 200 kW_{th} dual fluidized bed facility

Selina Hafner, Reinhold Spörl, Günter Scheffknecht

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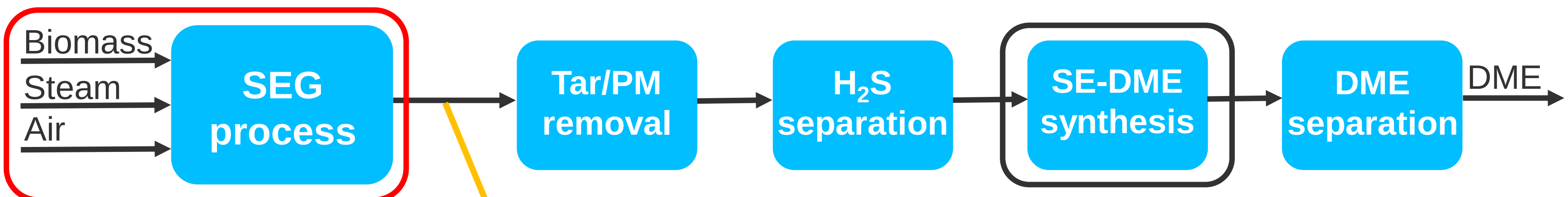
Motivation: Reduction of CO_2 emissions

Substitution of fossil fuels by liquid biofuels

- Dimethyl ether (DME):
  - Can be used in diesel engines with minor modifications
  - Simple handling and storage requirements
  - Clean combustion behaviour
- FLEDGED project: Novel biomass to DME process

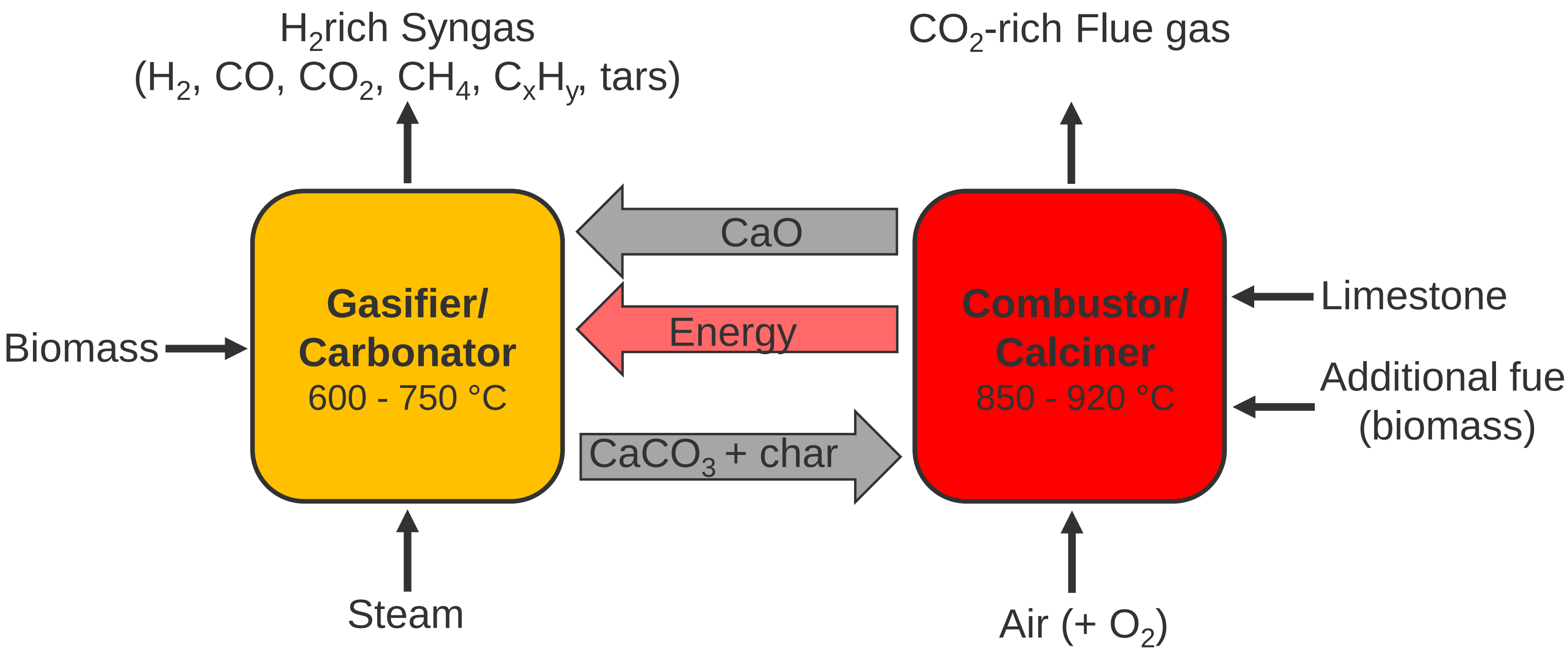


$$M = \frac{y_{H_2} - y_{CO_2}}{y_{CO} + y_{CO_2}} = 2$$

FLEDGED – FLexible Dimethyl ether production from biomass Gasification with sorption enhancED processes
SEG – Sorption enhanced gasification
PM – particulate matter
SEDMES – Sorption Enhanced DME Synthesis

Sorption Enhanced Gasification (SEG) Process

Introduction to the SEG process



<u>Gasifier/Carbonator</u>

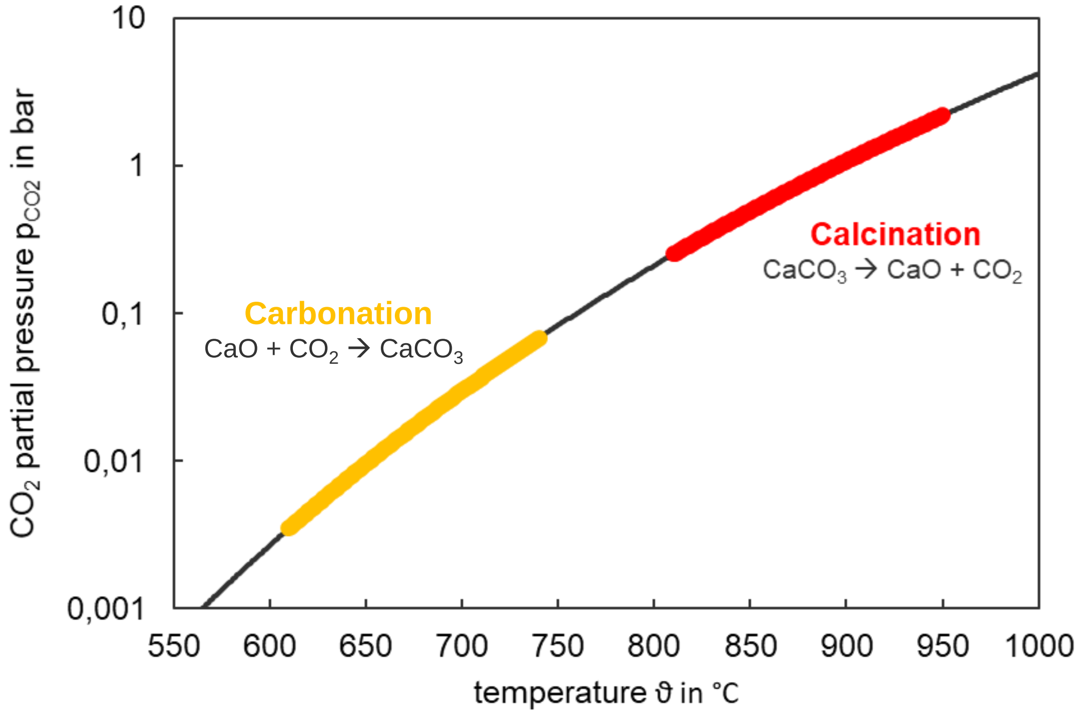
- Carbonation:
  $CaO + CO_2 \longrightarrow CaCO_3 \quad \Delta h_R<0$
- Water-gas-shift
  $CO + H_2O \longrightarrow CO_2 + H_2 \quad \Delta h_R<0$

<u>Combustor/Calciner</u>

- Calcination:
  $CaCO_3 \longrightarrow CaO + CO_2 \quad \Delta h_R>0$
- Char combustion
  $C + O_2 \longrightarrow CO_2 \quad \Delta h_R<0$

SEG process

$CaO/CaCO_3$ equilibrium



Calculated based on: Limestone Calcination Nearby Equilibrium: Kinetics, CaO Crystal Structure, Sintering and Reactivity
J. M. Valverde, P. E. Sanchez-Jimenez, and L. A. Perez-Maqueda
The Journal of Physical Chemistry C 2015 *119* (4), 1623-1641, DOI: 10.1021/jp508745u

SEG process

Properties and influencing parameters

- Production of a N_2 free syngas: no oxygen or external heating needed
- Adjustment of the C/H content in the syngas by CO_2 absorption

  ➡ syngas composition can be modified for different downstream synthesis processes
- Low tar contents in the syngas due to catalytic effect of CaO
- Low sulfur contents in the syngas (gasifier) and flue gas (calciner) due to sulfur capture by CaO

- Influencing parameters:
  - Biomass
  - Gasification temperature
  - Steam-to-Carbon ratio (S/C)
  - Looping ratio
  - …

Experimental setup

Experimental setup

200 kW_{th} SEG Pilot Plant

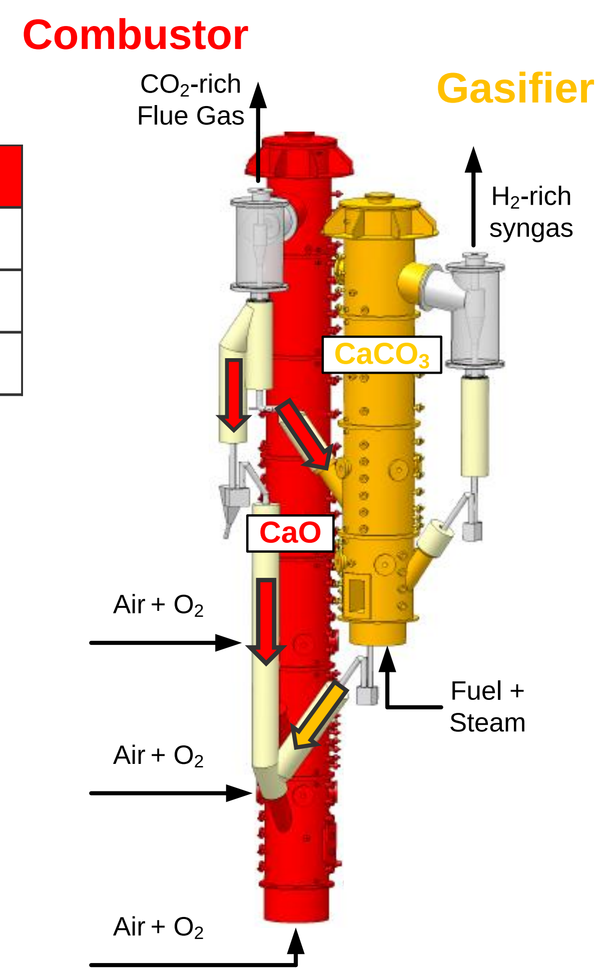
Gasifier/ Carbonator		Combustor/ Calciner	
Reactor height	6 m	Reactor height	10 m
Reactor diameter	0.33 m	Reactor diameter	0.21 m
Gas velocity	0.5 – 1.5 m/s	Gas velocity	3.5 – 6 m/s

- **Bubbling fluidized bed**

- No external heating
- Temperature controlled by solid looping rate
- Solid circulation rate is adjusted by a screw conveyor

- **Circulating fluidized bed**

- No external heating
- Temperature controlled by combustion of biomass and char particles from the gasifier



Experimental setup

Biomass and bed material composition

- Biomass: wood pellets

	H_u	γ_{H2O}	γ_{ash}	γ_V	γ_{FC}	γ_C	γ_H	γ_N	γ_S
	J/g,ad	wt%,ad	wt%,db	wt%,daf					
Wood pellets	17358	6.0	0.2	82.7	17.3	50.8	6.1	0.2	0.1

H_u – net calorific value   γ – mass fraction in the fuel   V – volatiles   FC – fixed carbon
ad – air dried   db – dry basis   daf – dry ash free

- Bed material: German limestone (d_P = 100 – 300 µm)

	x_{CaO}	x_{MgO}	x_{SiO2}	x_{Al2O3}	x_{others}	x_{CO2} 2)
	wt%, db					
German limestone 1)	55.4	0.7	0.4	0.1	0.2	43.7

1) Limestone analysis is not normalized to 100%
2) Mass fraction of CO_2 that is released as CO_2 during calcination

Experimental setup

Experimental parameters

- Biomass: wood pellets
- Bed material: German limestone (d_P = 100 – 300 µm)
- Gasification temperature $\vartheta_{Gasification}$: 600 – 774 °C

➡ controlled by transfer mass flow between Calciner and Gasifier

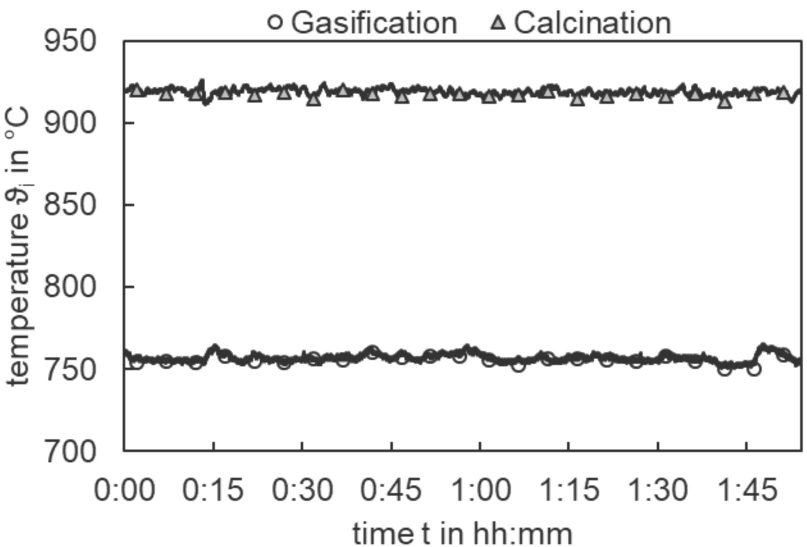
➡ syngas composition not only influenced by gasifier temperature, but also by the sorbent looping ratio

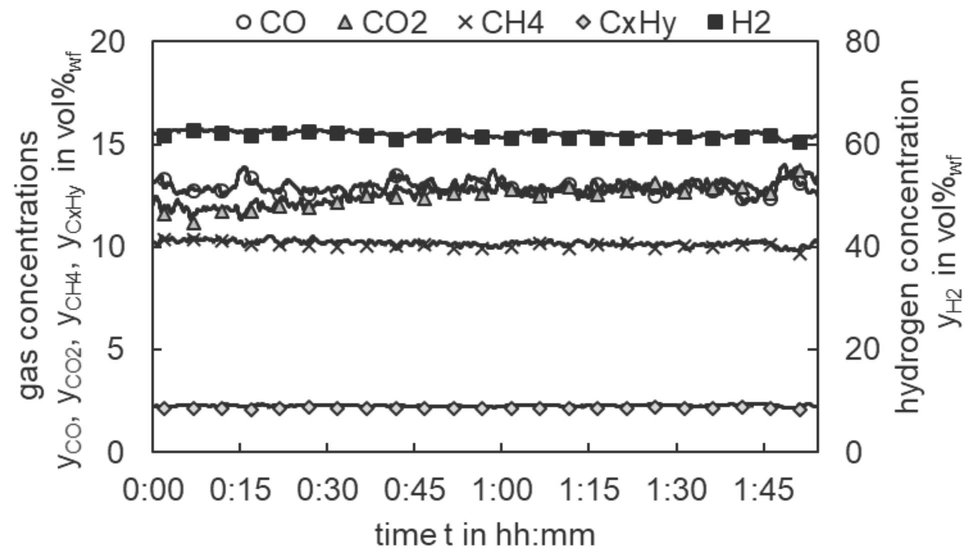
- Calcination temperature $\vartheta_{Calcination}$: 910 – 935 °C
- Steam-to-Carbon-ratio S/C: 1.5 mol_{H2O}/mol_C
- Steady state conditions at each experimental point: 1 – 3 h

Experimental results

Experimental results

Trends of temperatures and syngas composition



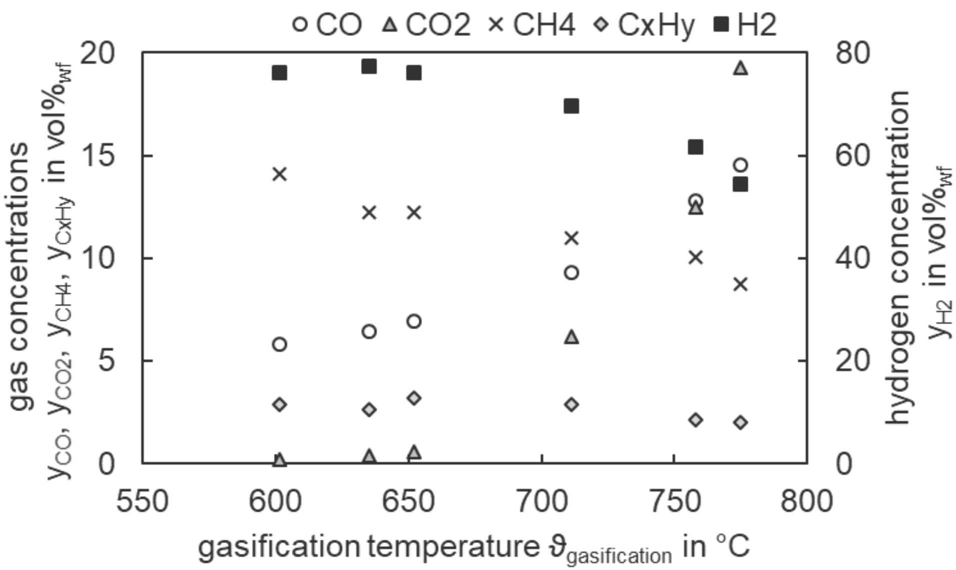


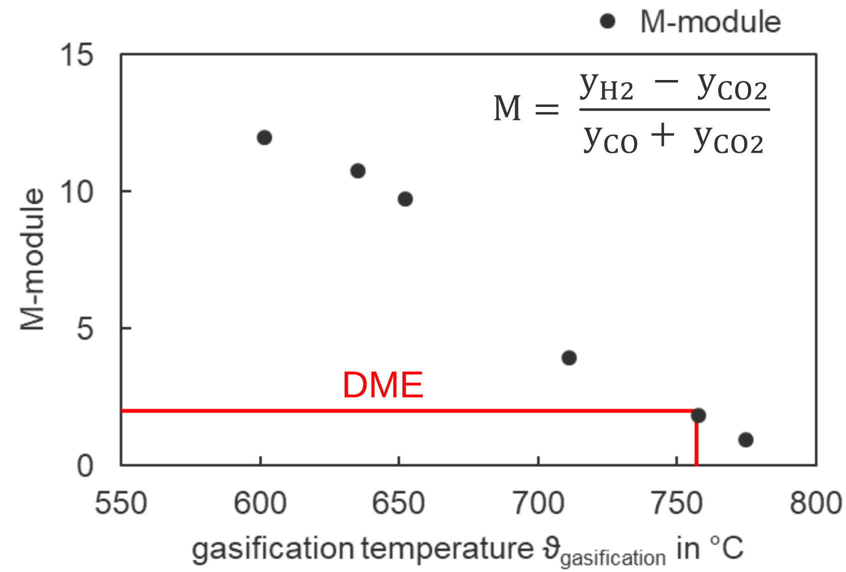
- Stable operation of the gasifier and calciner could be demonstrated
- Syngas composition at a gasification temperature of 757 °C:
  y_{H2} = 62 $vol\%_{wf}$ y_{CO} = 13 $vol\%_{wf}$ y_{CO2} = 13 $vol\%_{wf}$
  y_{CH4} = 10 $vol\%_{wf}$ y_{CxHy} = 2 $vol\%_{wf}$

Fuel: wood pellets
Bed material: limestone
S/C molar ratio:1.5
Gasification temperature: 757±8 °C
Calcination temperature: 919±8 °C

Experimental results

Gas concentrations and M-module vs. gasification temperature





- Increasing gasification temperature:
  - y_{H2} ⬇ y_{CO} ⬆ y_{CO2} ⬆

  ➡ M-module ⬇

  ➡ due to $CaCO_3$/ CaO – equilibrium
- gasification temperature of about 757 °C is needed for M = 2

Fuel: wood pellets
Bed material: limestone
S/C molar ratio:1.5
Gasifiation temperature: 600 - 774 °C
Calcination temperature: 910 - 935 °C

Summary and conclusion

Summary and conclusion

- Process can be operated at stable conditions in a 200 kW_{th} DFB pilot scale facility with flexible variation of the gasification temperature between 600 and 774 °C
- Syngas composition/ M-module is strongly influenced by gasification temperature
  - ➡ due to the temperature dependency of the $CaCO_3$/CaO equilibrium
  - ➡ SEG is very flexible in regard to the adjustment of the syngas composition for a subsequent synthesis process
- Gasification temperature of about 757 °C is needed for M = 2
  - ➡ suitable for production of DME by sorption enhanced DME synthesis process

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www.fledged.eu

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University of Stuttgart
Germany

Thank you!

Selina Hafner

e-mail selina.hafner@ifk.uni-stuttgart.de
phone +49 (0) 711 685-67806
fax +49 (0) 711 685-63491

Universität Stuttgart
Institut für Feuerungs- und Kraftwerkstechnik
Pfaffenwaldring 23 • 70569 Stuttgart • Germany

ifk