Sorption enhanced Gasification – Pilot scale experimental campaigns in dual circulating fluidized beds

Selina Hafner, Max Schmid

University of Stuttgart
Institute of Combustion and Power Plant Technology
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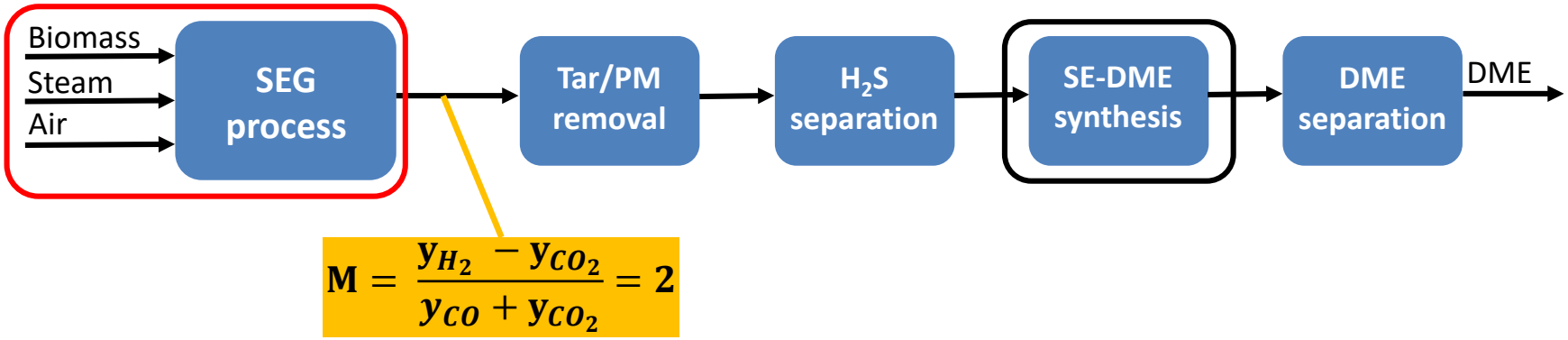
Motivation: Validation of SEG process at pilot scale

FLEDGED project: Novel biomass to DME process

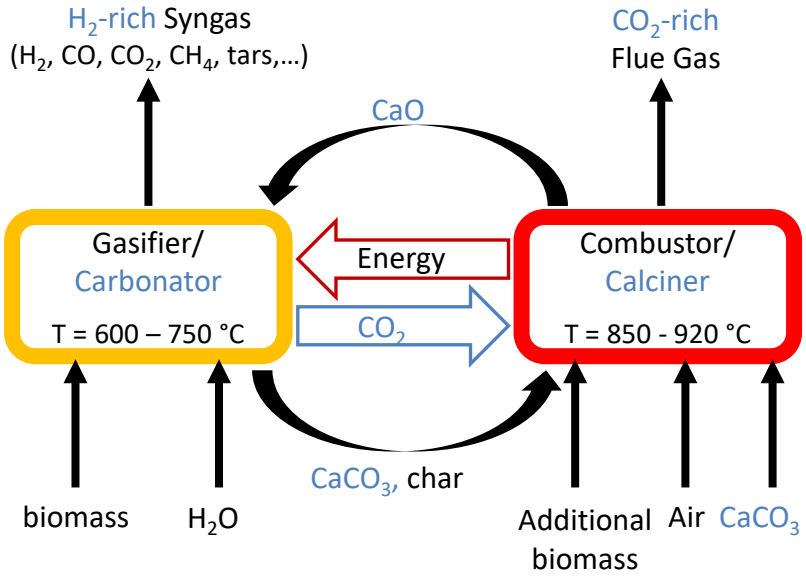


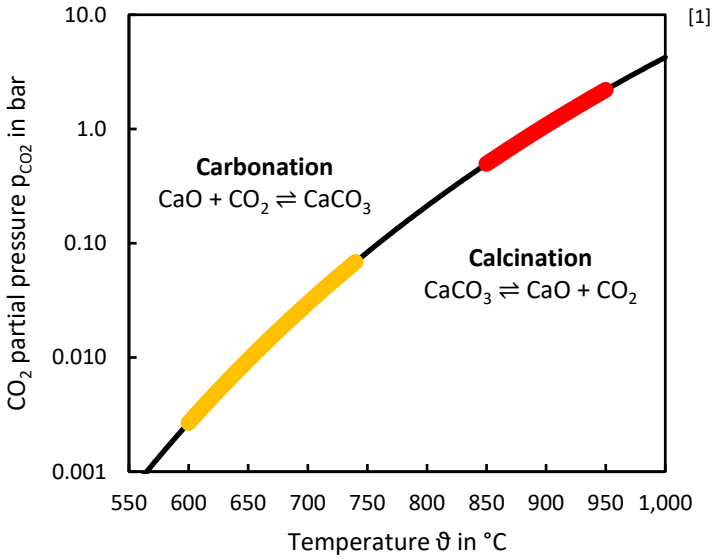
Target: <u>Production of a tailored syngas for Dimethyl Ether synthesis</u>

- $\mathrm{M} = \frac{y_{H_2} - y_{CO_2}}{y_{CO} + y_{CO_2}} = 2$
- With and without hydrogen addition
- From different feedstocks:
  - Wood pellets
  - Municipal solid waste pellets

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

SEG process





Gasifier/ Carbonator

$CaO + CO_2 \rightleftharpoons CaCO_3$ exothermal

$CO + H_2O \rightleftharpoons CO_2 + H_2$ exothermal

Combustor/ Calciner

$CaCO_3 \rightleftharpoons CaO + CO_2$ endothermal

$C + O_2 \rightleftharpoons CO_2$ exothermal

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

Pilot scale dual fluidized bed facility

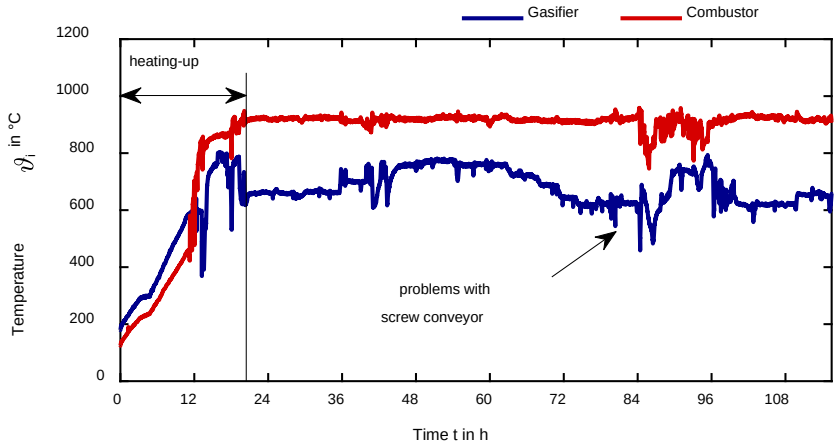
Gasifier/ Carbonator		Combustor/ Calciner	
Reactor height	6 m	Reactor height	10 m
Reactor diameter	0.33 m	Reactor diameter	0.21 m

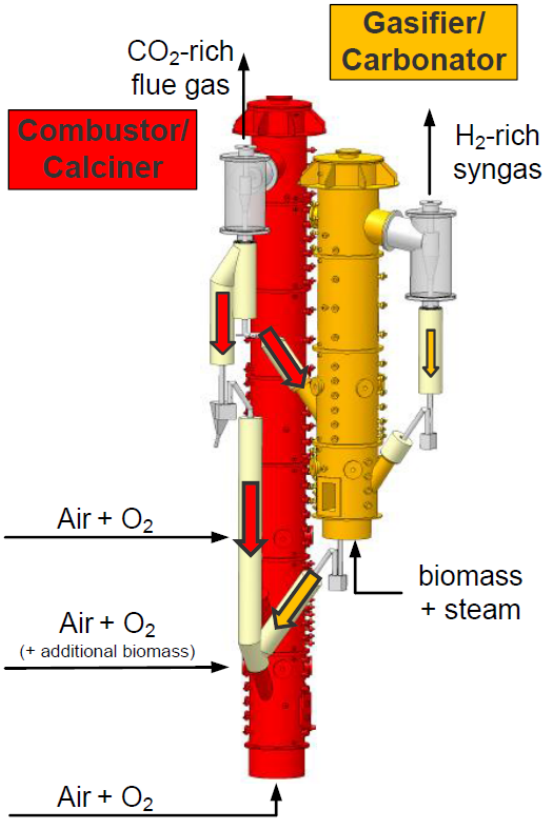
Bubbling fluidized bed

- 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





200 kW_{th} dual fluidized bed facility at University of Stuttgart

Experimental setup: Biomass and limestone composition

- Biomass: Wood pellets and MSW pellets

	H_u	γ_{H2O}	γ_{ash}	γ_V	γ_{FC}	γ_C	γ_H	γ_N	γ_S	γ_{Cl}
	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	0.02
MSW pellets Batch 1	11622	8.0	33.2	90.0	10.0	53.9	6.4	2.5	0.6	1.0
MSW pellets Batch 2	12712	10.7	26.2	88.7	11.3	51.6	6.7	2.6	0.6	1.0

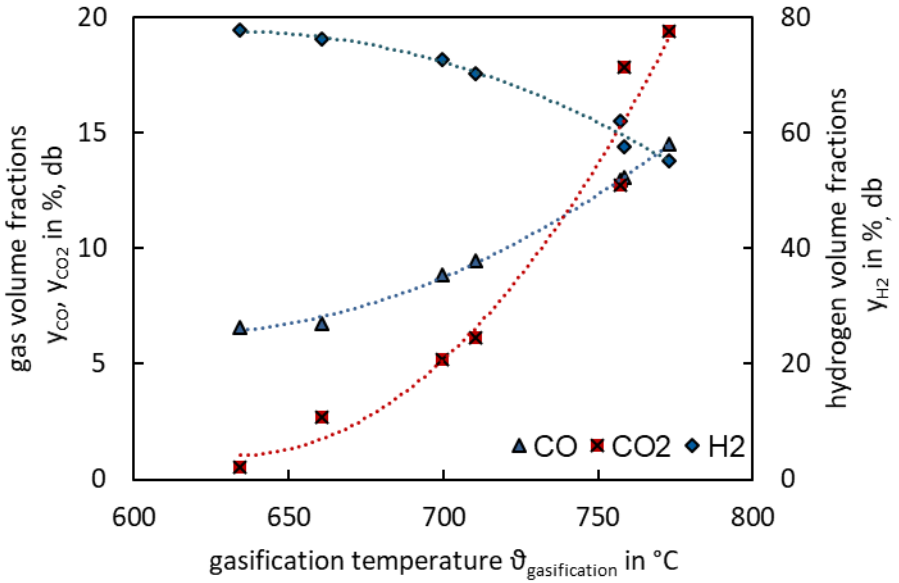
H_u – net calorific value γ – mass fraction in the fuel V – volatiles FC – fixed carbon
ad – air dried db – dry basis daf – dry ash free

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

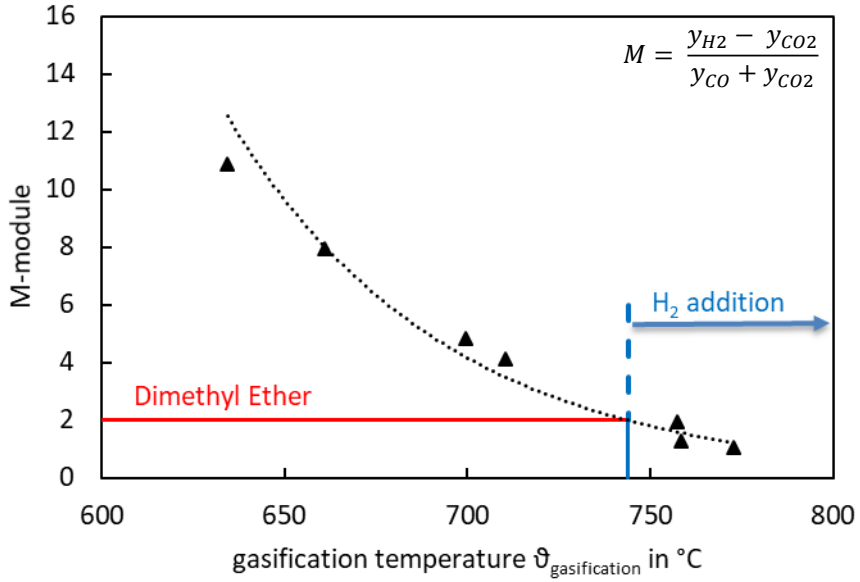
	x_{CaO}	x_{MgO}	x_{SiO2}	x_{Al2O3}	others	x_{CO2}[1]
	wt%, db					
Limestone	55.1	0.7	0.4	0.1	0.2	43.5

[1]Mass fraction of CO_2 that is released as CO_2 during calcination

Experimental results: T-variation with wood pellets



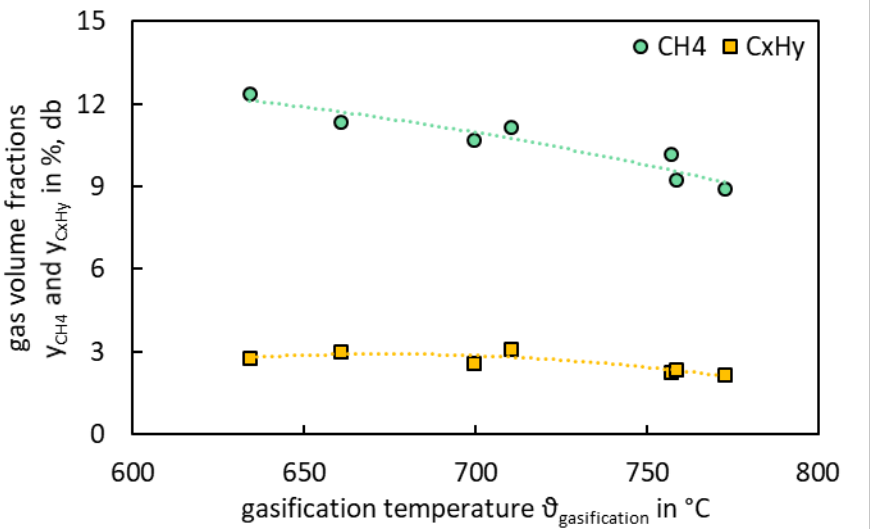
- H_2-concentrations up to 78 %
- Less CO_2-capture at higher temperatures due to $CaO/CaCO_3$-equilibrium
  - → Lower H_2-concentrations
  - → Higher CO and CO_2 concentrations

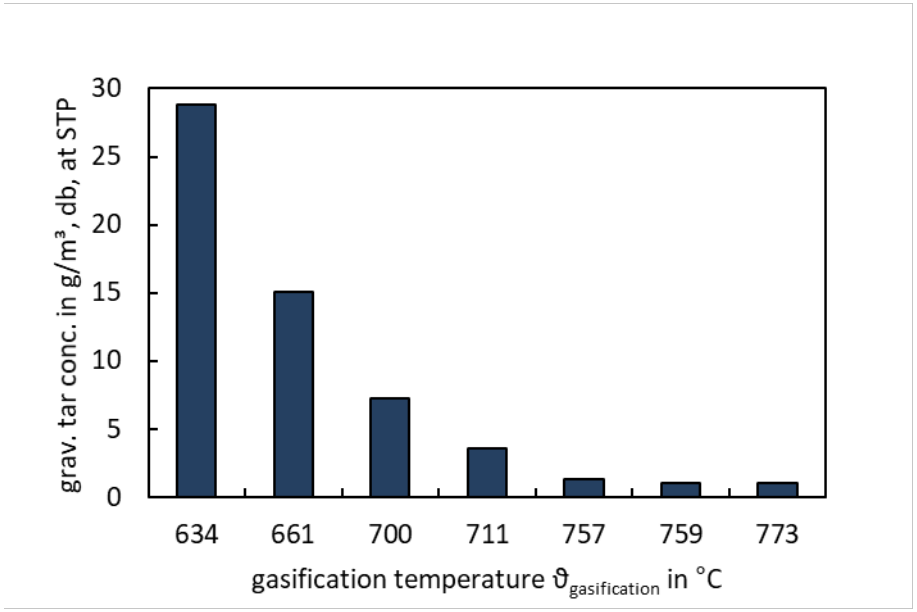


- Flexible adjustment of syngas composition
  - → Production of syngas for different downstream synthesis processes
  - → Integration of electrolysis hydrogen possible → operation at higher temperature

Biomass: wood pellets
S/C molar ratio: 1.5
Gasification temp.: 635 - 773°C

Experimental results: T-variation with wood pellets





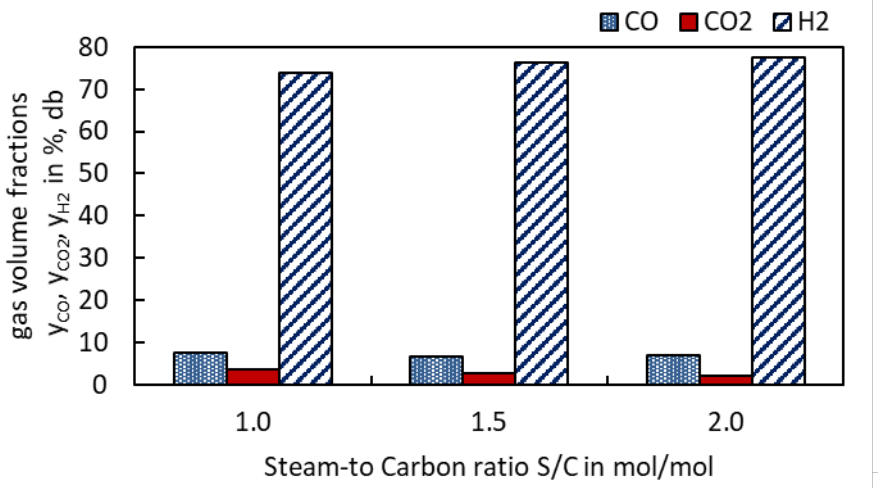
- CH_4 volume fraction decreases with increasing gasification temperature
- C_xH_y volume fraction is almost constant up to 710 °C, after which it decreases

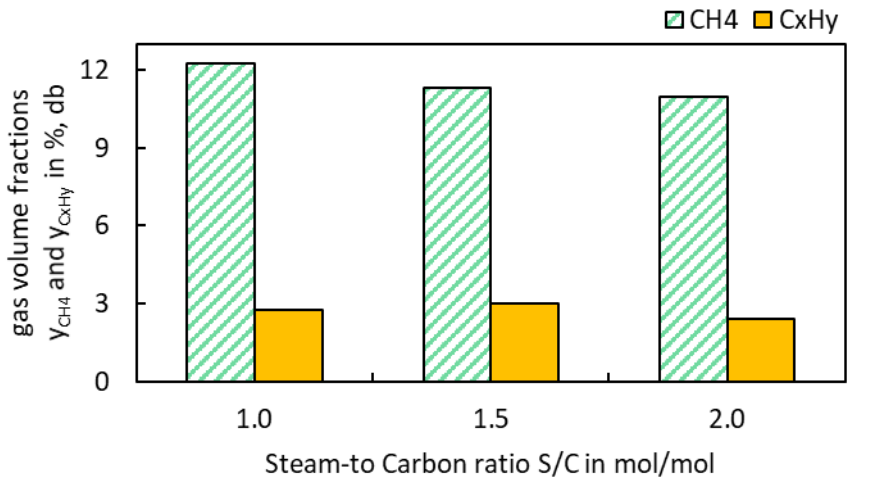
- Tar content can be reduced significantly by increasing the gasification temperature

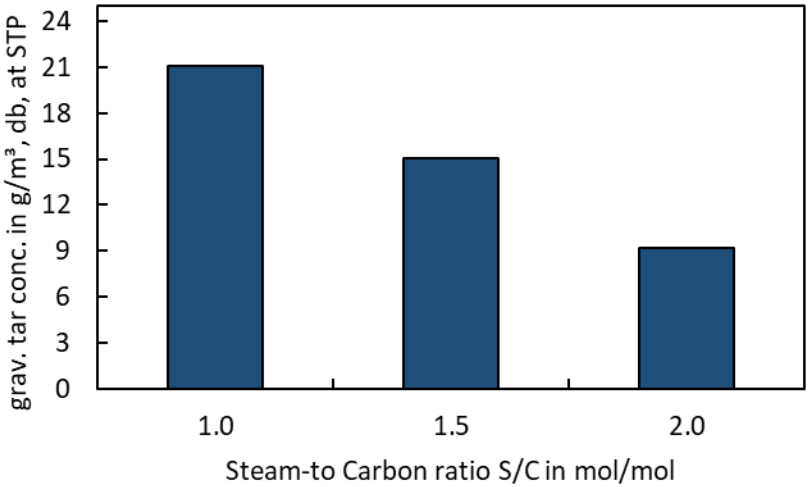
C_xH_y: C_2H_4, C_2H_6, C_3H_6, C_3H_8 and C_4H_{10}

Biomass: wood pellets
S/C molar ratio: 1.5
Gasification temp.: 635 - 773°C

Experimental results: S/C-variation with wood pellets



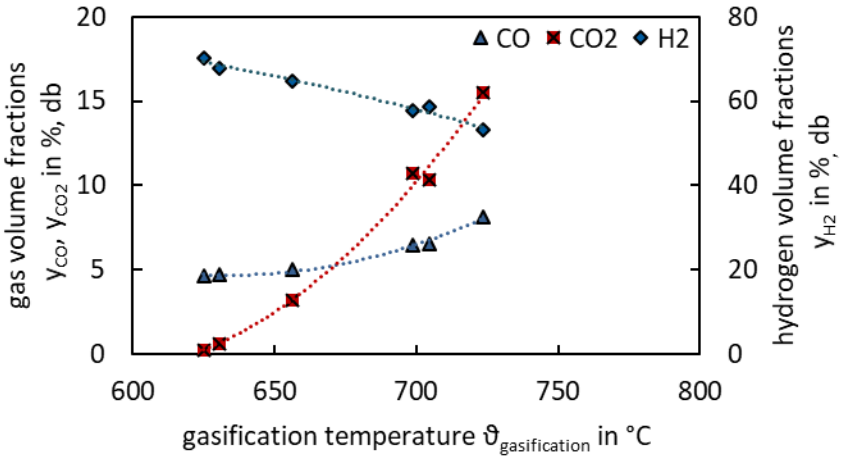


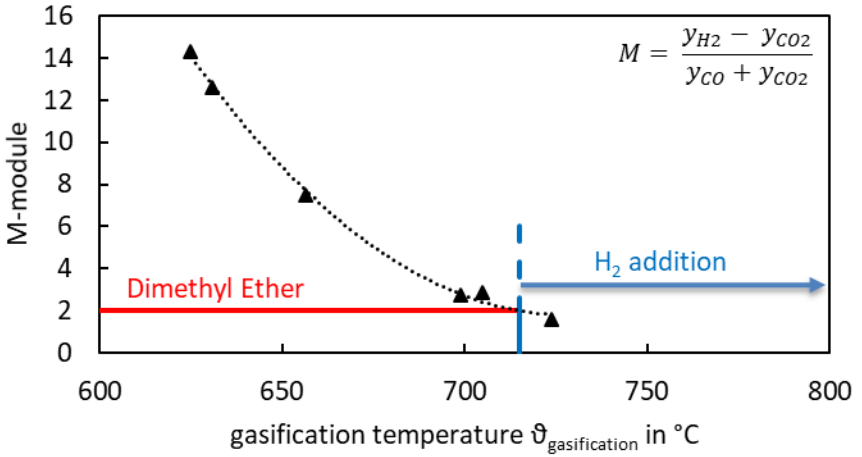


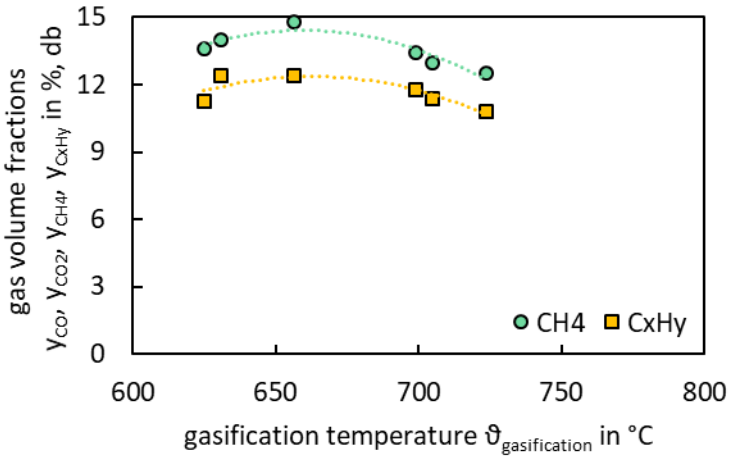
- Enhanced H_2 volume fraction at higher S/C ratio
- Reduced CH_4 volume fraction at higher S/C ratio
- Tar concentration is strongly influenced by S/C ratio → reduced concentration for higher S/C

Biomass: wood pellets
S/C molar ratio: 1 - 2
Gasification temp.: 661 ± 3°C

Experimental results: T-variation with ECO pellets







- SEG process can be operated stably with MSW pellets as feedstock
- H_2 volume fractions up to 70 vol%, db
- Flexible adjustment of syngas composition

Biomass: MSW pellets
S/C molar ratio: 1.5
Gasification temp.: 625 - 724°C

Summary

- SEG process has been operated stably in the DFB pilot scale facility at the University of Stuttgart with wood pellets and municipal solid waste pellets
- Syngas composition/ M-module is strongly influenced by gasification temperature
  - → due to the temperature dependency of the $CaCO_3$/CaO equilibrium
  - → M =2, which is required for DME synthesis has been achieved for both feedstocks
  - → SEG is very flexible in regard to the adjustment of the syngas composition for a subsequent synthesis process
  - → flexible syngas production for process operation with and without integration of electrolysis hydrogen possible
- S/C ratio has no strong influence on the permanent gas composition/ M-module, but strongly influences the tar content in the syngas

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