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Syngas production for DME synthesis from Sorption Enhanced Gasification of Biomass: A Pilot Plant-based Case Study

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ICPS19 International Conference on Polygeneration Strategies
18th November 2019

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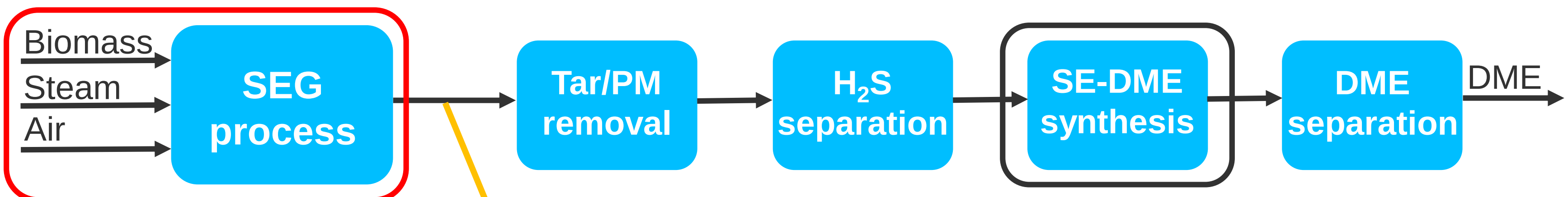
Motivation: Reduction of CO_2 emissions

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



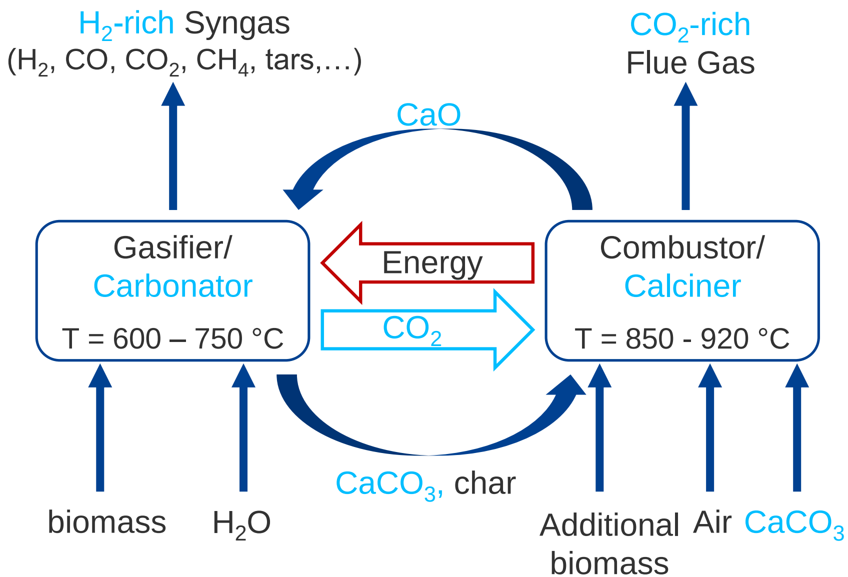
$$M = \frac{y_{H_2} - y_{CO_2}}{y_{CO} + y_{CO_2}} = 2$$

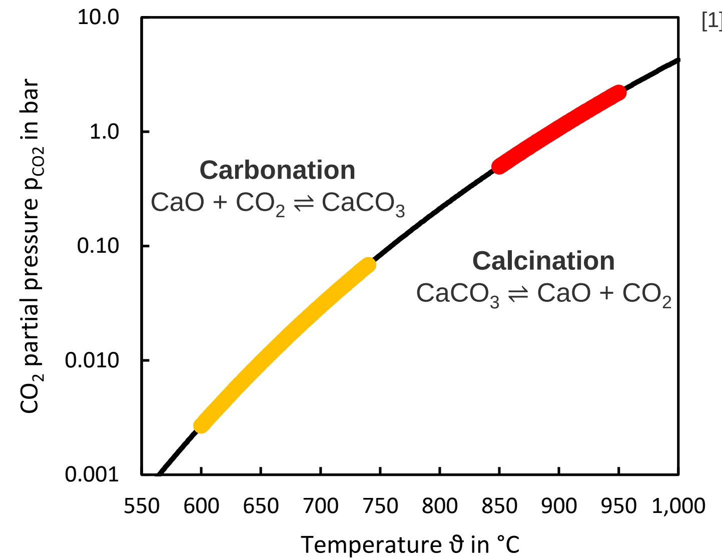
FLEDGED – FLExible Dimethyl ether production from biomass Gasification with sorption enhancED processes
SEG – Sorption enhanced gasification
PM – particulate matter
SEDMES – Sorption Enhanced DME Synthesis

Sorption Enhanced Gasification (SEG) Process

Process description

Sorption enhanced Gasification (SEG)





Gasifier/ Carbonator

$CO + H_2O \rightleftharpoons CO_2 + H_2$ exothermal

$CaO + CO_2 \rightleftharpoons CaCO_3$ exothermal

Combustor/ Calciner

$C + O_2 \rightleftharpoons CO_2$ exothermal

$CaCO_3 \rightleftharpoons CaO + CO_2$ endothermal

[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

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

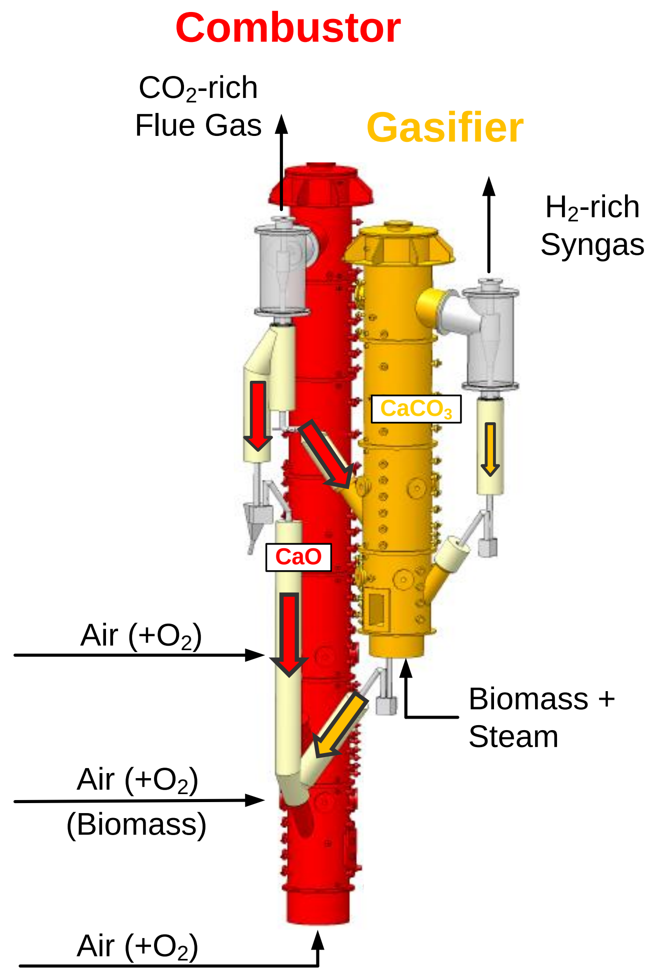
Gasifier/ Carbonator		Combustor/ Calciner	
Reactor height	6 m	Reactor height	10 m
Reactor diameter	0.33 m	Reactor diameter	0.21 m
Gas velocity	0.5 – 1.5 m/s	Gas velocity	3.5 – 6 m/s

- **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		Proximate analysis				Ultimate analysis						
		$\gamma_{H2O,ad}$	$\gamma_{ash,db}$	$\gamma_{V,daf}$	$\gamma_{FC,daf}$	$\gamma_{C,daf}$	$\gamma_{H,daf}$	$\gamma_{O,daf}$	$\gamma_{N,daf}$	$\gamma_{S,daf}$	$\gamma_{Cl,daf}$	H_u
		wt%				wt%						MJ/kg
	wood	6.0	0.2	82.7	17.3	50.8	6.1	42.8	0.2	0.1	<0.1	17.4
	OFMSW	8.0	33.2	90.0	10.0	53.9	6.4	35.6	2.5	0.6	1.0	11.6

Bed material	x_{CaO}	x_{MgO}	x_{SiO2}	x_{Al2O3}	x_{others}	x_{CO2} [1)]
	wt%					
Limestone (d_P = 100 – 300 µm)	55.1	0.7	0.4	0.1	0.2	43.5

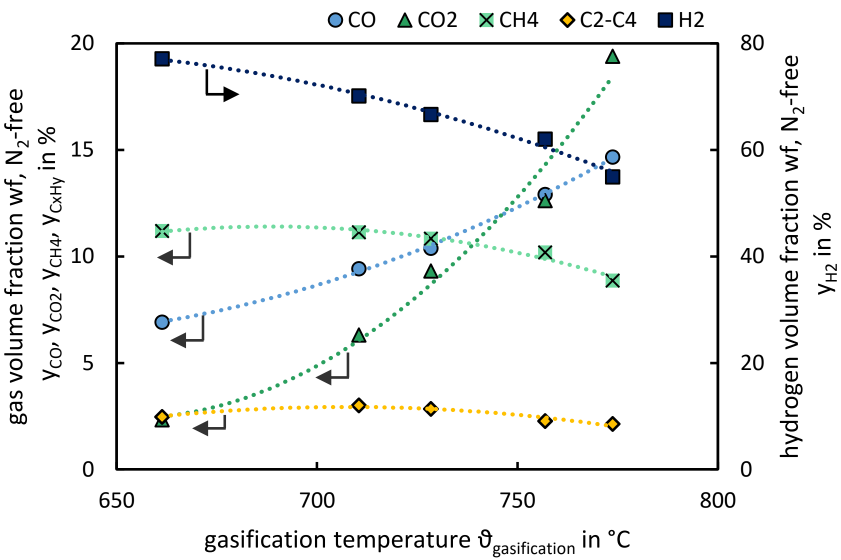
1) Mass fraction of CO_2 that is released during calcination

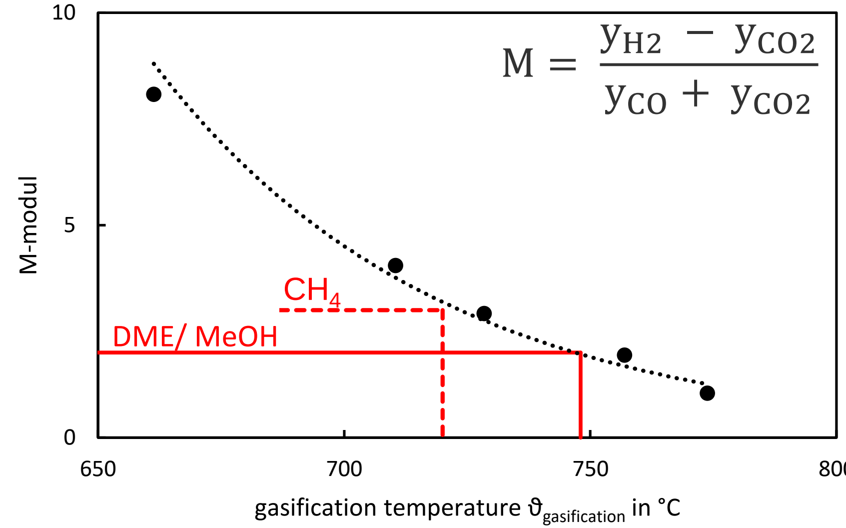
OFMSW – organic fraction of municipal solid waste
H_u – net calorific value γ – mass fraction in the fuel V – volatiles FC – fixed carbon
ad – air dried db – dry basis daf – dry ash free

Experimental results

Experimental results

Temperature variation with wood pellets as fuel





- 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

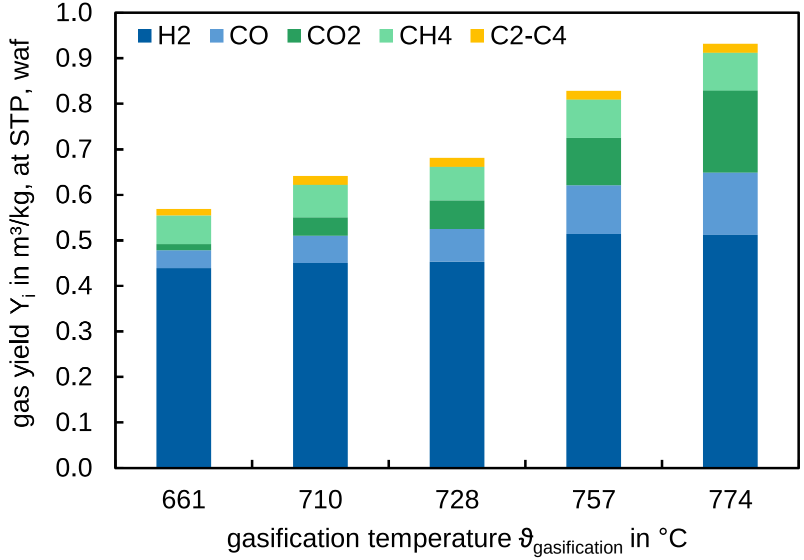
- Flexible adjustment of syngas composition

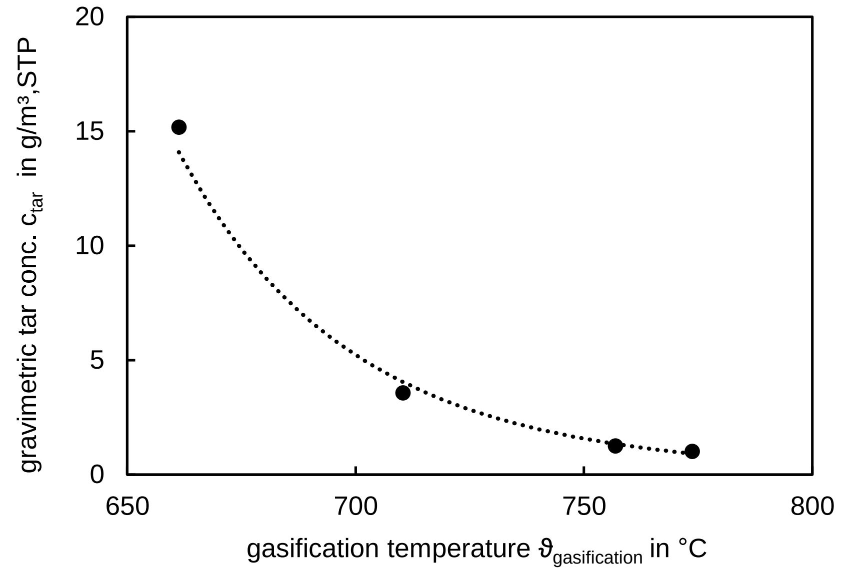
→ Production of syngas for different downstream synthesis processes

→ Integration of electrolysis hydrogen possible → operation at higher temperature

Experimental results

Temperature variation with wood pellets as fuel



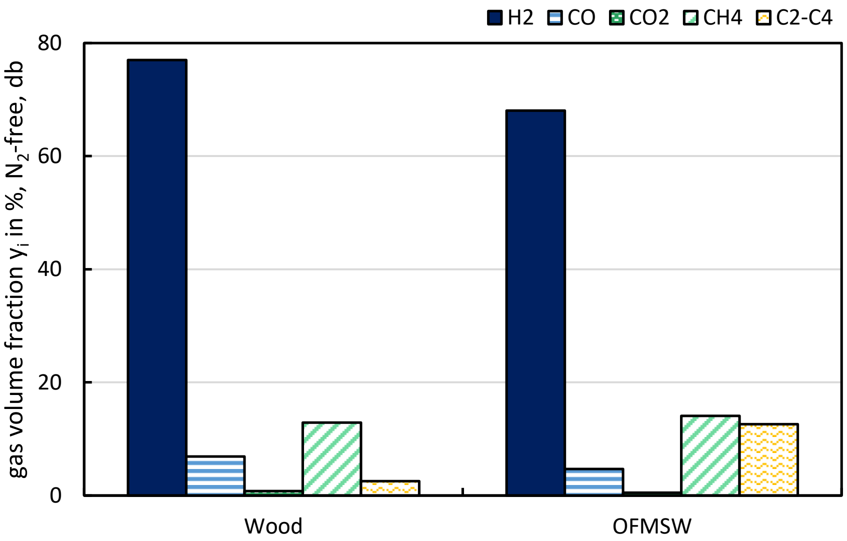


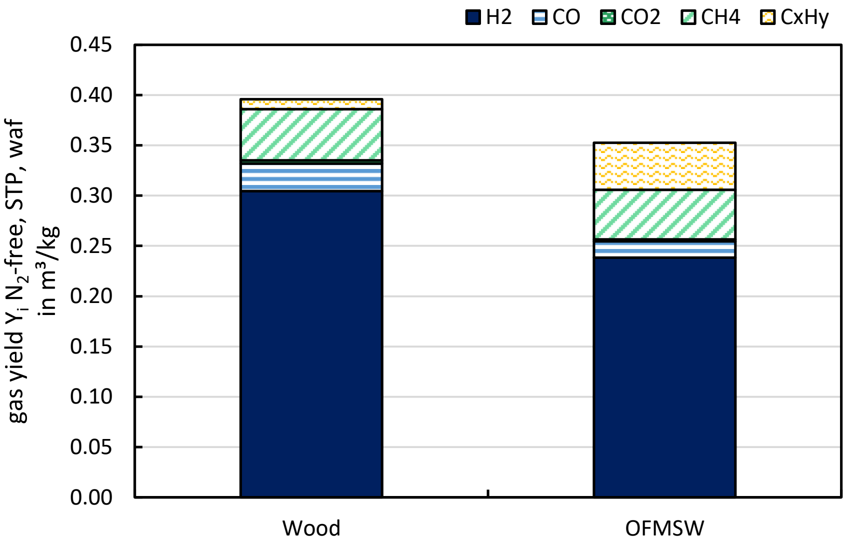
- Strong influence of the gasification temperature on the gas yield

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

Experimental results

Comparison of SEG with wood and OFMSW





- SEG of OFMSW compared to wood:
  - Lower H_2-concentrations
  - Significantly higher concentrations of light hydrocarbons (C2-C4)
  - Lower gas yield

S/C molar ratio: 1.5
Gasification temp.: 635 ±1°C

Summary and conclusion

Summary and conclusion

- SEG process can be operated stably in a 200 kW_{th} DFB pilot scale facility with wood pellets and a flexible variation of the gasification temperature
- 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
- It has been demonstrated, that the SEG-process can also be operated with OFMSW

Acknowledgement

The FLEDGED project has received funding from the European Union`s Horizon 2020 research and innovation programme under grant agreement No 727600.

www.fledged.eu

Disclaimer: *The European Commission support for the production of this publication does not constitute endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

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Thank you!

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