PILOT SCALE EXPERIMENTAL CAMPAIGNS IN DUAL CIRCULATING FLUIDIZED BEDS

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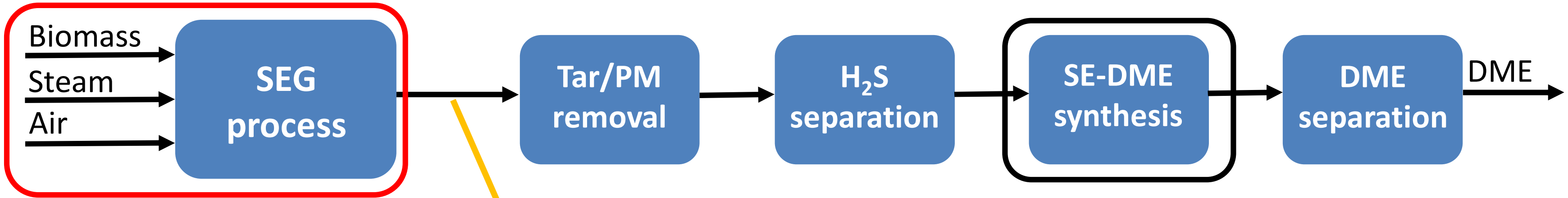
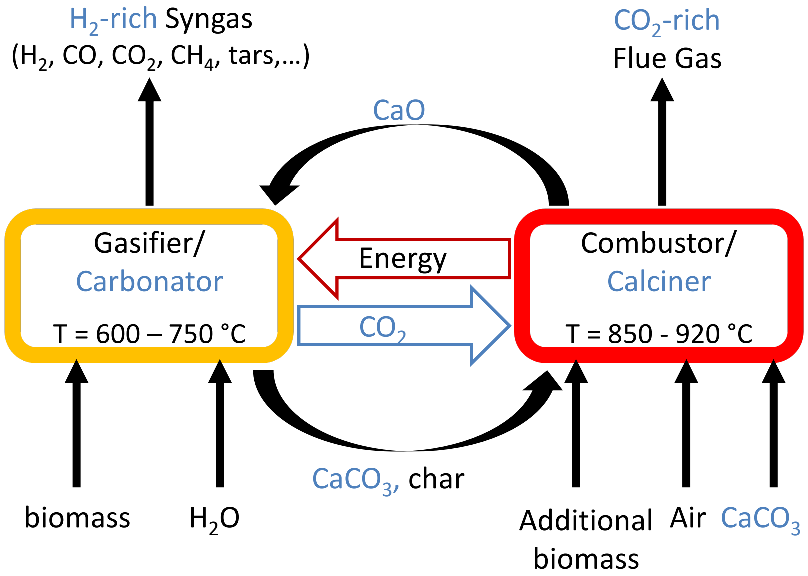
Motivation: Validation of SEG process at pilot scale

FLEDGED project: Novel biomass to DME process



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

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



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

Pilot scale dual fluidized bed facility

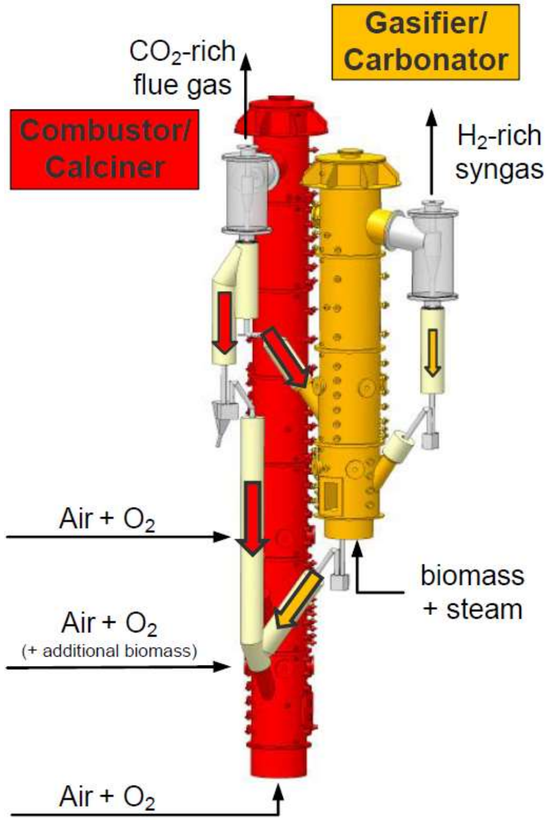
Gasifier/ Carbonator		Combustor/ Calciner	
Reactor height	6 m	Reactor height	10 m
Reactor diameter	0.33 m	Reactor diameter	0.21 m

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 dual fluidized bed facility at University of Stuttgart

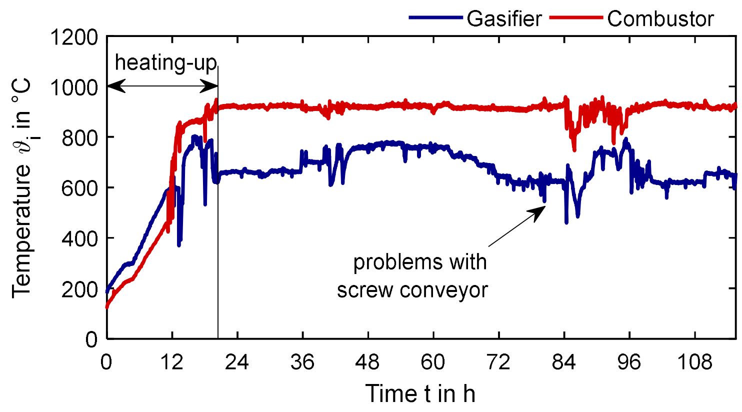
Pilot scale dual fluidized bed facility

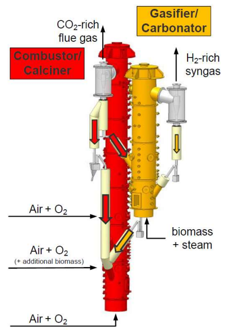
Measurement methods

- Plenty of **temperature** measurements and **pressure** transducers
- Continuous measurement of **gas flows** in and out of the reactors
- Measurement of **transfer mass flow** between combustor and gasifier
- Frequent **solid sampling** from gasifier bottom loop seal and combustor loop seal
- Continuous gas measurement of **permanent gases**
- Semi-continuous measurement of **lower hydrocarbons** (C_2H_4, C_2H_6, C_3H_6, C_3H_8, C_4H_{10})
- Wet chemical sampling of **tars** according to the tar protocol (CEN/TS 15439)

Experimental procedure

- Operation 24/7 in a 3 shift mode
- Heating up with a natural gas burner followed by combustion of wood pellets





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

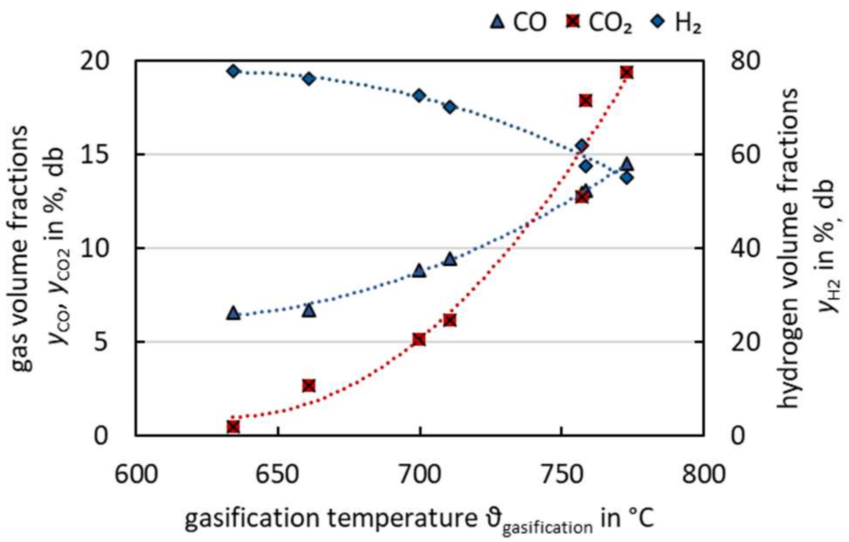
H_u – net calorific value γ – mass fraction in the fuel V – volatiles FC – fixed carbon
ad – air dried db – dry basis daf – dry ash free

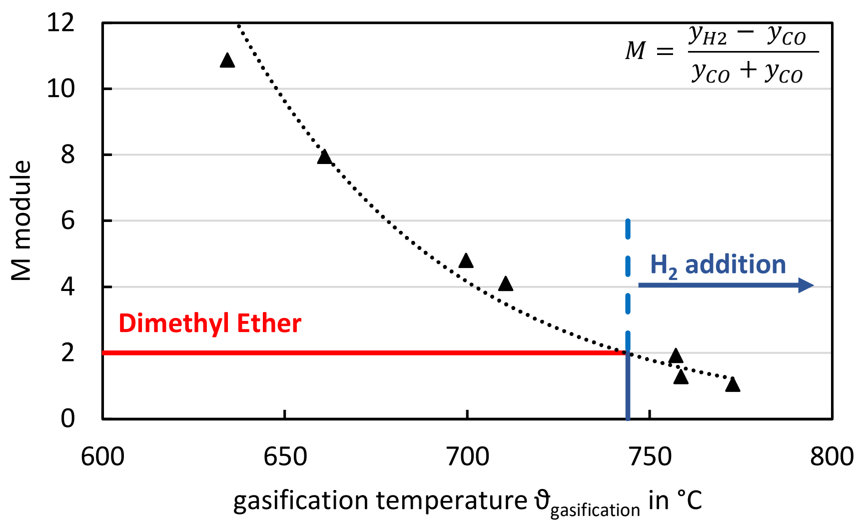
- Bed material: Limestone (d_P = 100 – 300 µm)

	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



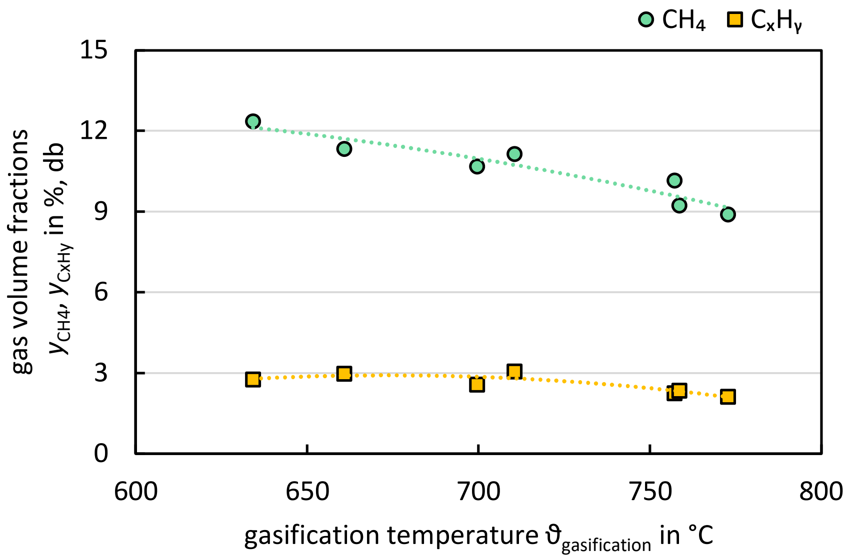


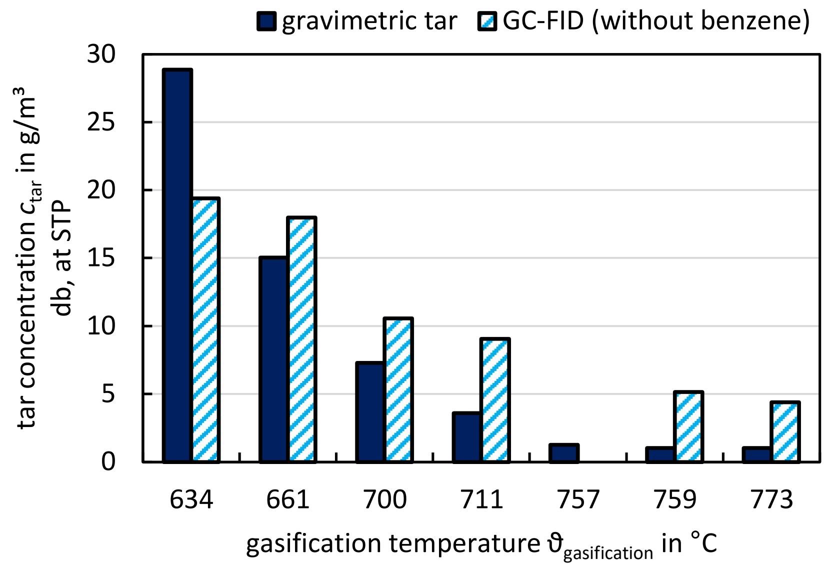
- H_2-concentrations up to 77 %
- enhanced CO_2-capture at lower temperatures due to CaO/$CaCO_3$-equilibrium
  → Higher H_2 production due to water-gas-shift reaction

- Flexible adjustment of syngas composition
  → Production of tailored syngases for different downstream synthesis processes
  → Integration of electrolysis hydrogen possible

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

Experimental results: T-variation with wood pellets





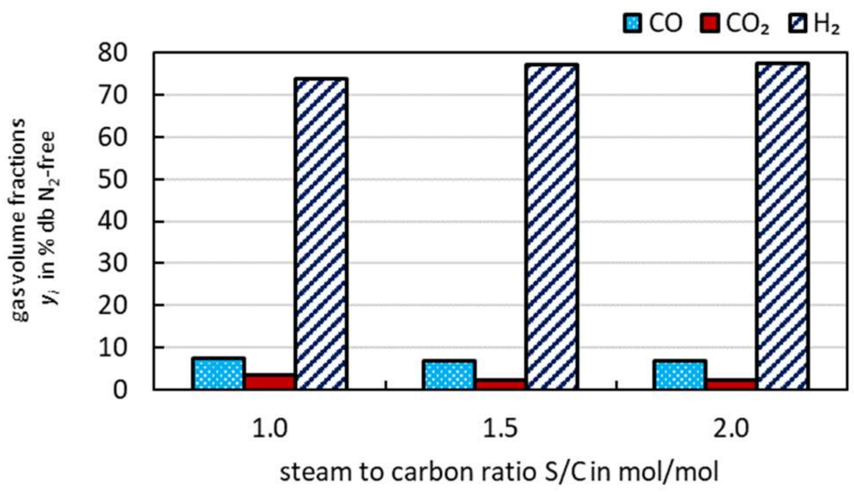
- CH_4 volume fraction decreases with increasing gasification temperature
- C_xH_y volume fraction is almost constant up to 710 °C, after which it slightly decreases

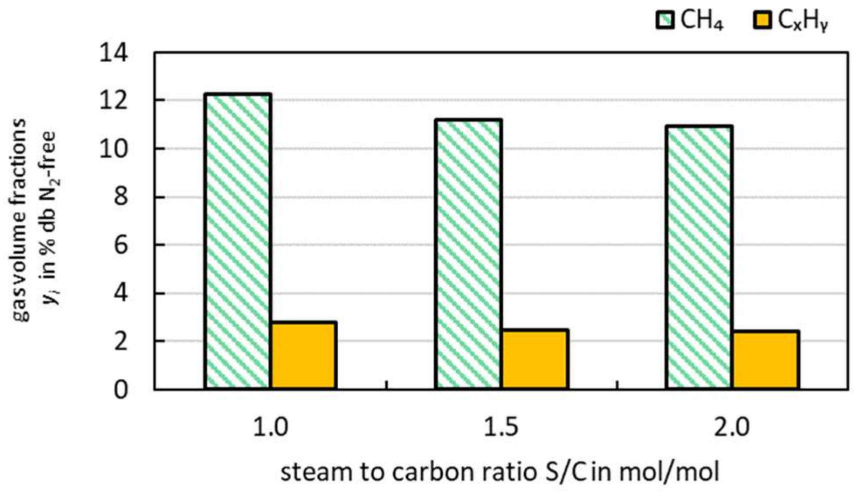
- Tar content can be reduced significantly by increasing the gasification temperature
- For $\vartheta_{gasification}$ >660 °C higher amount of GC-FID tars → enhanced share of light tars

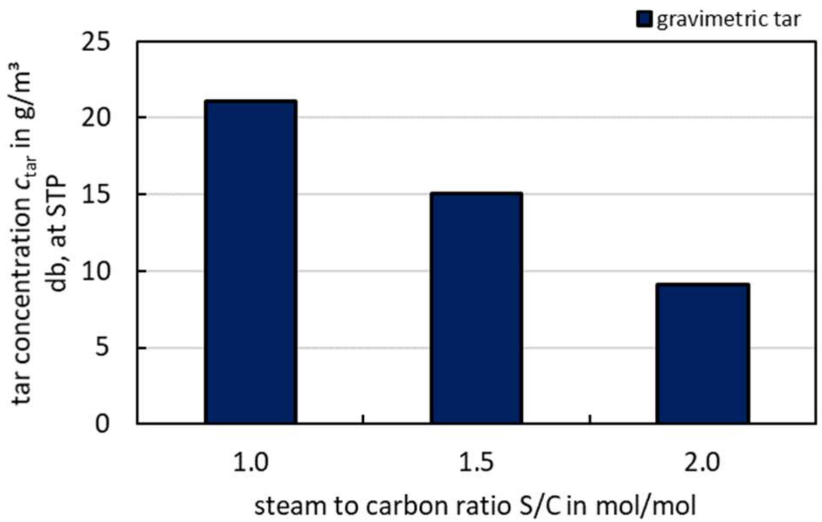
C_xH_y: C_2H_4, C_2H_6, C_3H_6, C_3H_8 and C_4H_{10}

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

Experimental results: S/C-variation with wood pellets





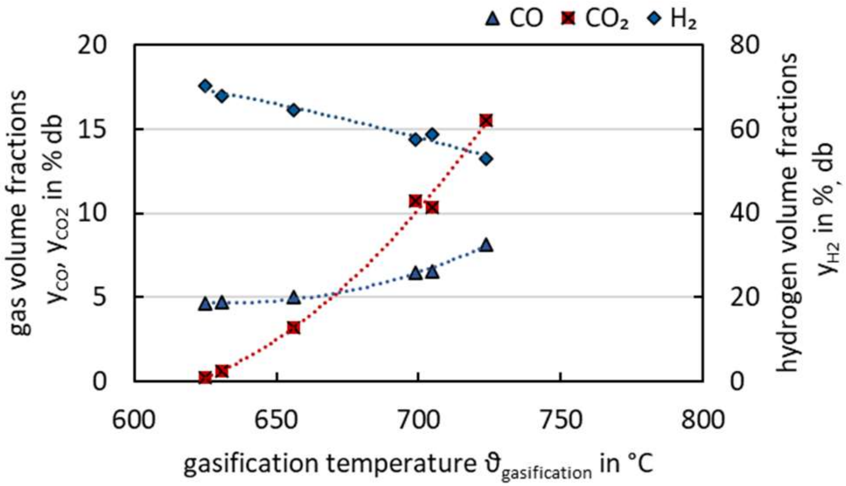


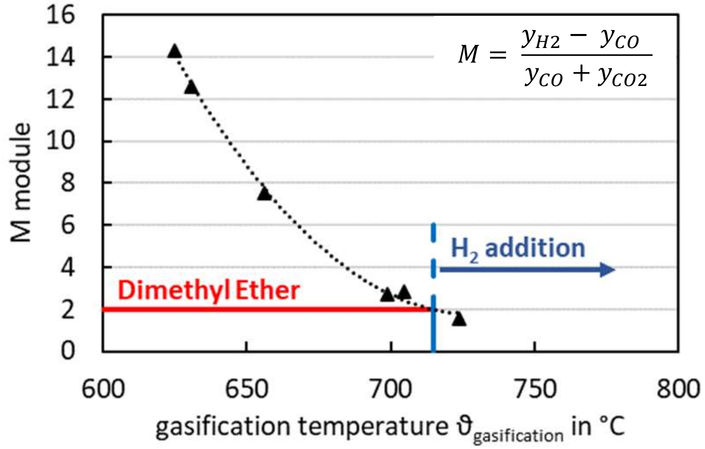
- Enhanced H_2 and reduced CO volume fraction at higher S/C ratio
  → WGS reaction shifted towards product side
- Reduced CH_4 volume fraction at higher S/C ratio
- Tar content is significantly reduced by increasing S/C ratio

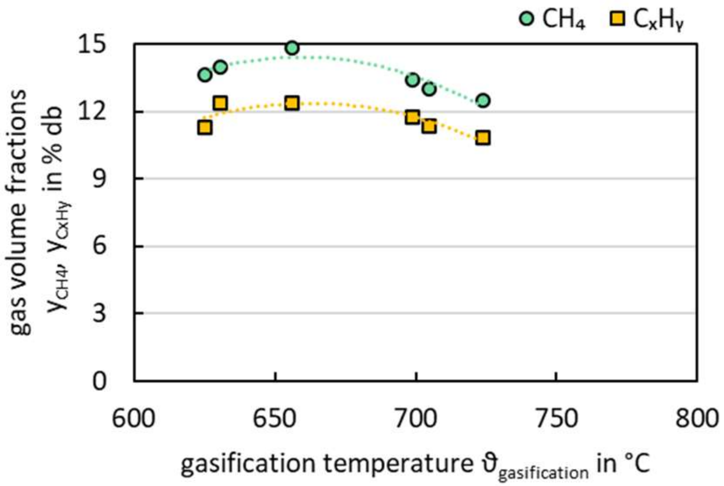
C_xH_y: C_2H_4, C_2H_6, C_3H_6, C_3H_8 and C_4H_{10}

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

Experimental results: T-variation with MSW 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
- High CH_4 and C_xH_y volume fractions

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

Summary

- **Successfull operation of the SEG process** with wood and MSW pellets, without remarkable operational problems
- Production of syngases with **variable H_2/CO/CO_2 ratio** possible for both feedstocks
  - **Tailored syngas** production **for DME** synthesis with and without H_2 addition
- **Gasification temperature** is the operating variable **influencing most** syngas quality (yield, composition, tars)
- Tar content can strongly be influenced by variation of the steam to carbon ratio
- SEG with MSW pellets results in reduced H_2 and CO contents and enhanced contents of CH_4, lower hydrocarbons and tars compared to wood pellets

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