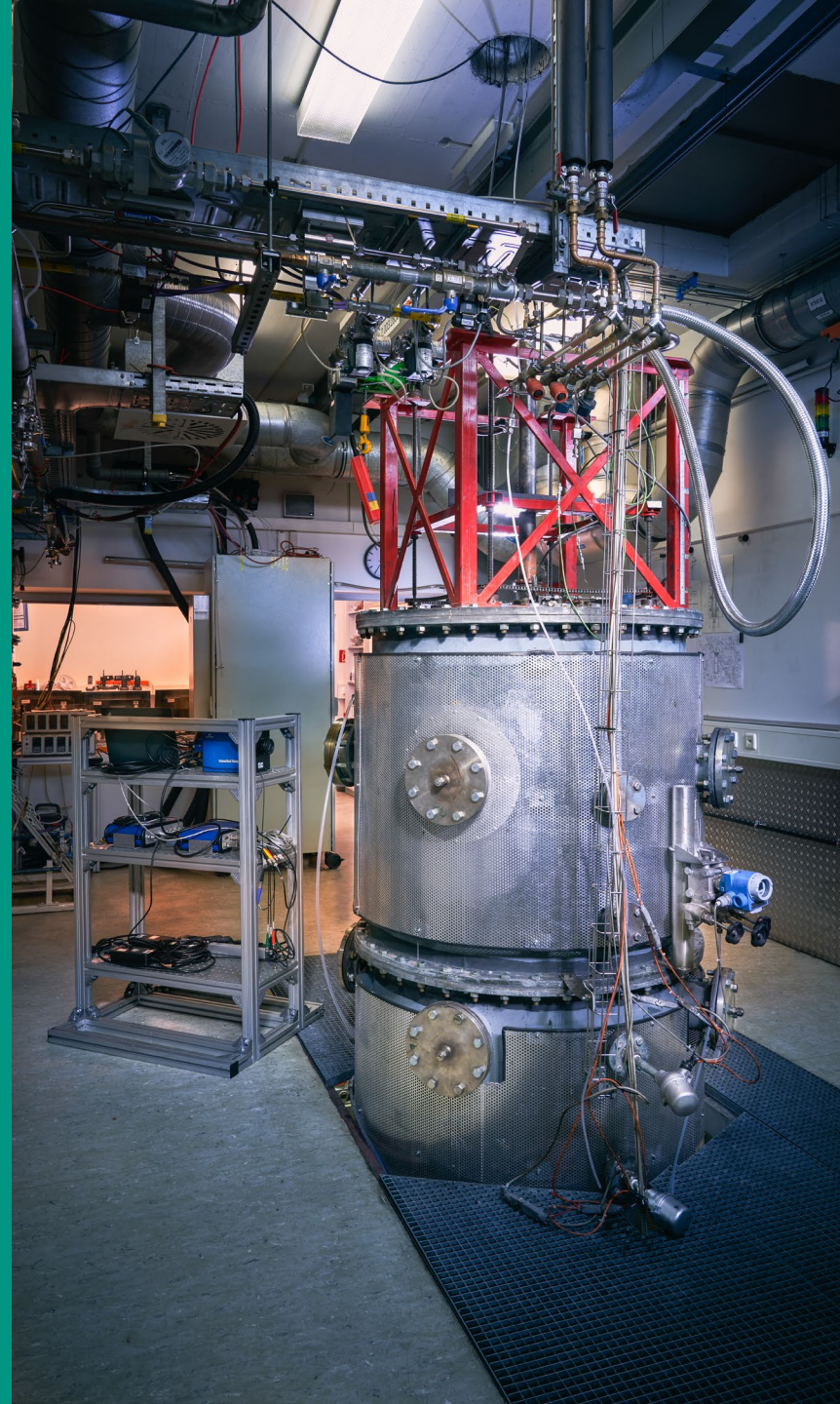


Conversion of Plastic Waste Based Pyrolysis Oil under Entrained Flow Gasification Conditions

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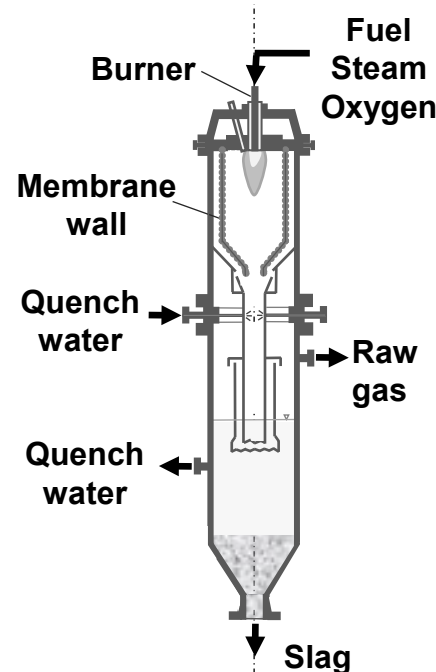
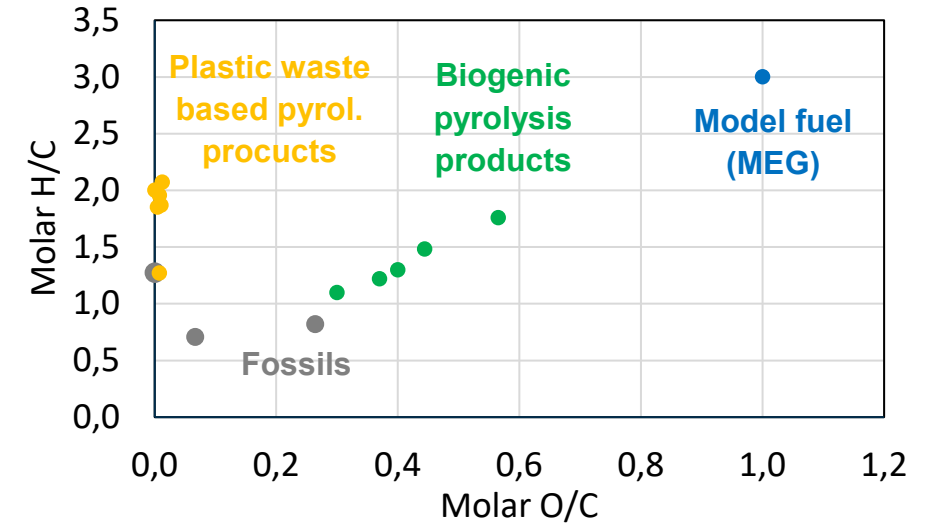
Entrained Flow Gasification (EFG) of Waste Based Fuels

Goal: optimal operation of existing EFG with new feedstock

- High carbon conversion
- Fuel flexible operation
- Minimization of by-products: soot, tar, hydrocarbons

Challenge

- Biogenic and waste based feedstocks feature heterogeneous specification
- Fuel conversion influenced by
 - Fuel characteristics
 - Atomization
 - Temperature field
 - Reactand mixing and flow field



	LHV MJ/kg	Σ (N,S,Cl) wt%	Ash wt%
Model fuel (MEG)	17	0	0
Wood oil	22	0.18	0.20
Wood slurry	24	0.32	0.64
Plastic oil	42	0.19	0

Influence of Fuel Specification on Conversion and Energy Efficiency

Experiments at 5 MW Pilot High Pressure Entrained Flow Gasifier at KIT

(p = 40 bar, T = 1300 °C)

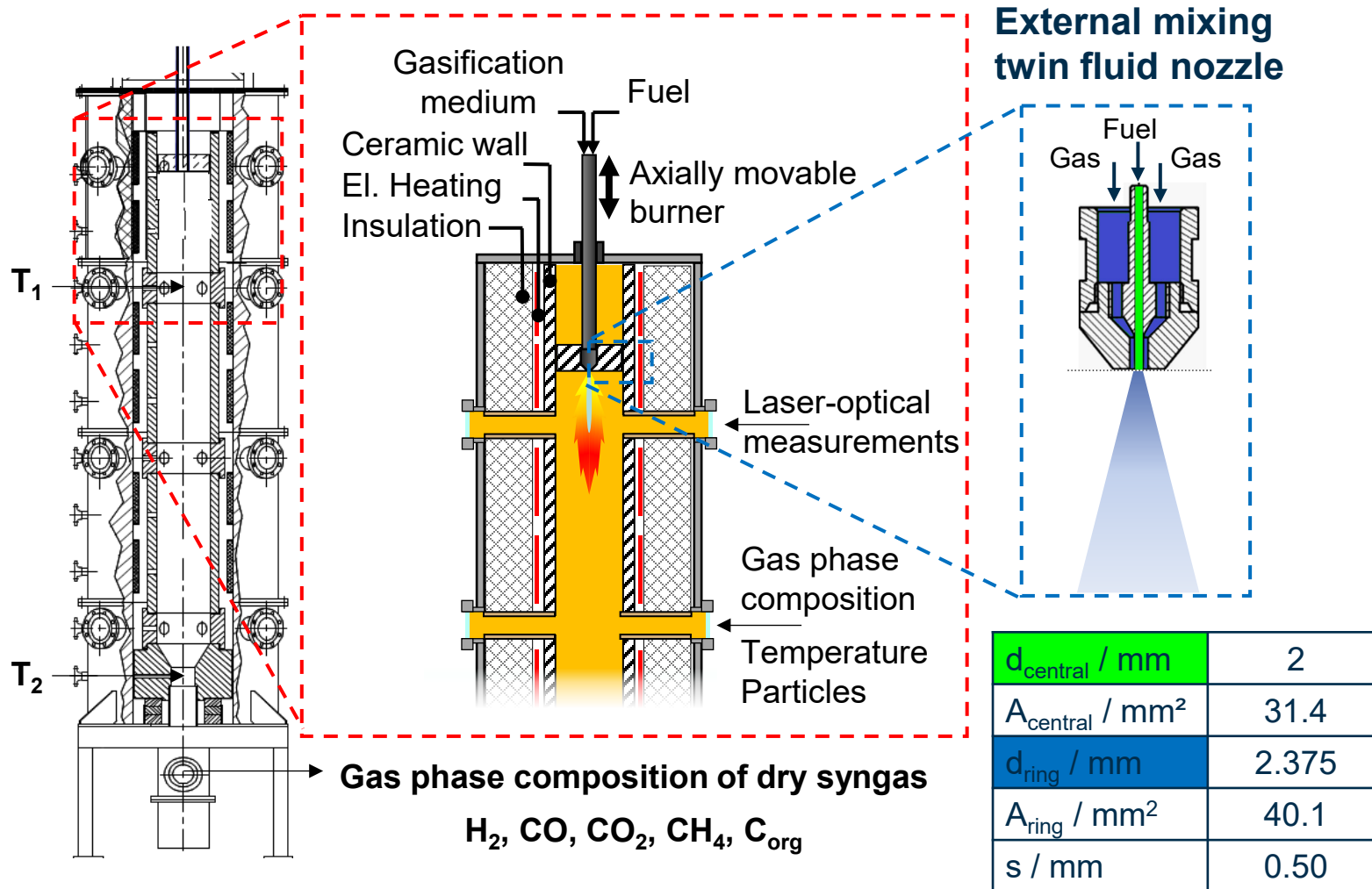
	MEG	Wood oil	Plastic oil
P_{th} / MW	4.8	5.0	6.3
λ_{tech}	0.54	0.55	0.45
Steam/Fuel / kg/kg	0.33	0.39	0.52
GLR / kg/kg	55	55	68
CGE / %	55	55	58
Yield (H ₂ +CO) / m ³ _{STP} /MWh fuel	164	166	207

Higher heating value and carbon content of plastic oil:

- Operation of existing gasifiers with higher load
- Lower stoichiometry leads to higher efficiency (CGE, yield (H₂+CO))
- Increased GLR (gas to liquid ratio) improves atomization
- H₂/CO only slightly influenced due to higher steam supply

Experiments under Atmospheric EFG Conditions

Research Entrained flow Gasifier REGA



Technical data:

$$p = 1 \text{ bar}$$

$$\text{Reactor length} = 3 \text{ m}$$

$$\text{Inner diameter} = 0.28 \text{ m}$$

$$\text{Electrical heating: } 60 \text{ kW}$$

$$T_{wall} = 1195 \text{ }^{\circ}\text{C}$$

$$T_{gas,max} = 1600 \text{ }^{\circ}\text{C}$$

Gasification medium:

$$O_2/N_2/steam$$

$$y_{O_2,max} = 80 \text{ vol\%}$$

Fuel Specification and Operating Parameters

Mixed plastic waste



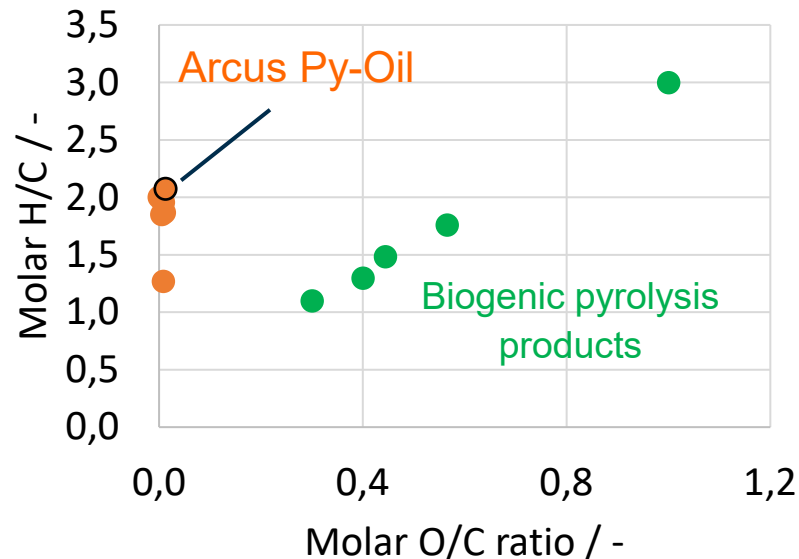
Twin-screw reactor, $T = 500\text{ }^{\circ}\text{C}$
Demoplant TRL 8



Pyrolysis oil



Fuel specification

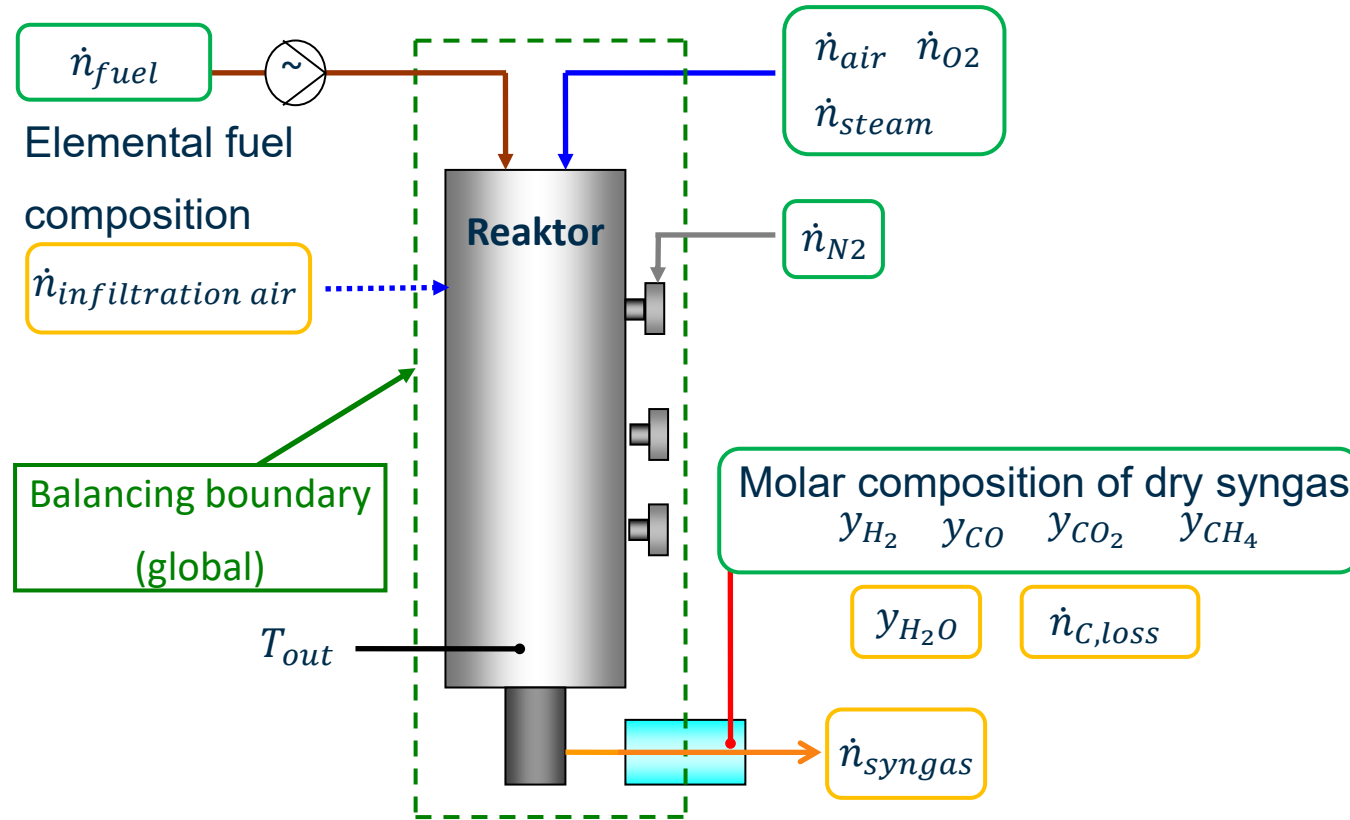


C	wt%	83.3
H	wt%	14.5
H/C	mol/mol	2,07
O/C	mol/mol	0,012
LCV	MW	41.7

Operating parameters

$P_{th,fuel}$	kW	100
$\dot{M}_{fuel}$	kg/h	8.6
$y_{O_2,GM}$	vol%	62.9 – 79.9
λ_{tech}	-	0.45
$\dot{M}_{steam}$	kg/h	2.6 – 4.4
$\dot{M}_{steam} / \dot{M}_{fuel}$	kg/kg	0.31 – 0.51

Balancing → Characteristic Parameters



Assumptions:

N₂ inert

Cl, S react completely to HCl, H₂S

Loss with H/C = 0.8

Elemental balance: C, H, N, O

→ Analytically not accessible data

→ Characteristic parameters:

Carbon conversion:

$$CC_{fuel} = \frac{\dot{n}_{syngas} \cdot (y_{CO} + y_{CO_2} + y_{CH_4})}{\dot{n}_{C,fuel}}$$

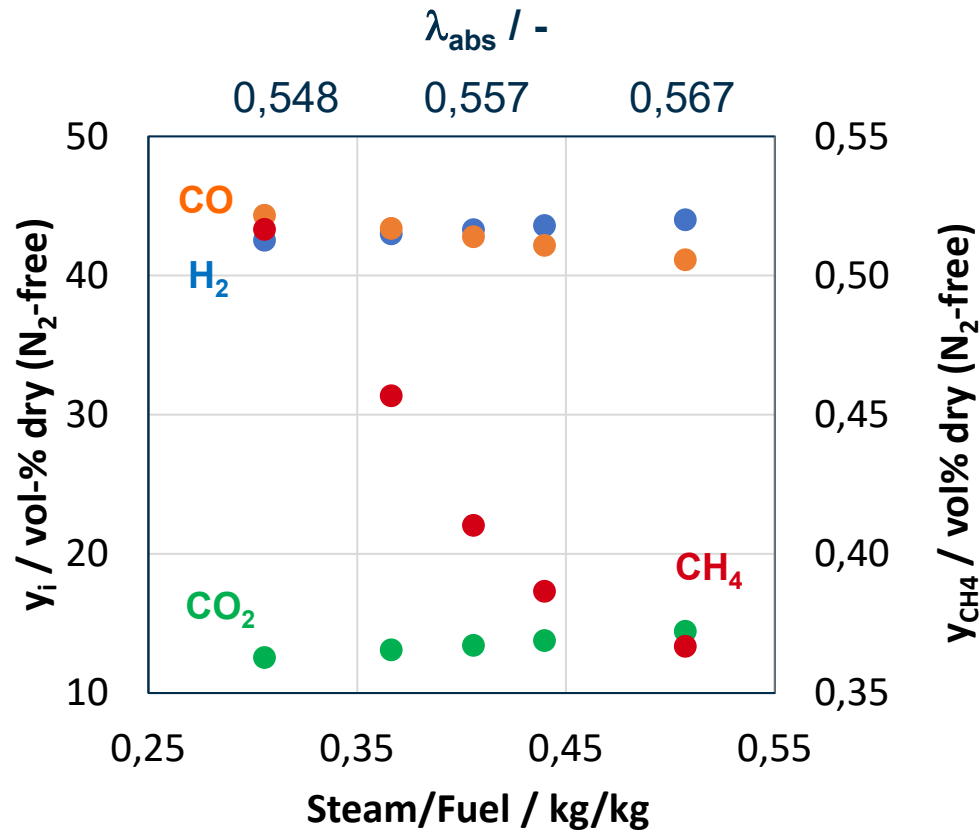
Yield of H₂ and CO:

$$Yield(H_2 + CO) = \frac{\dot{n}_{syngas} \cdot (y_{H_2} + y_{CO})}{\dot{m}_{fuel}}$$

Oxidation rate of reactand mixture:

$$\lambda_{abs} = \frac{\dot{n}_{syngas} \cdot (2 \cdot y_{CO_2} + y_{CO} + y_{H_2O})}{2 \cdot \dot{n}_{C,syngas} + 0,5 \cdot \dot{n}_{H,syngas}}$$

Influence of Steam on Syngas Composition

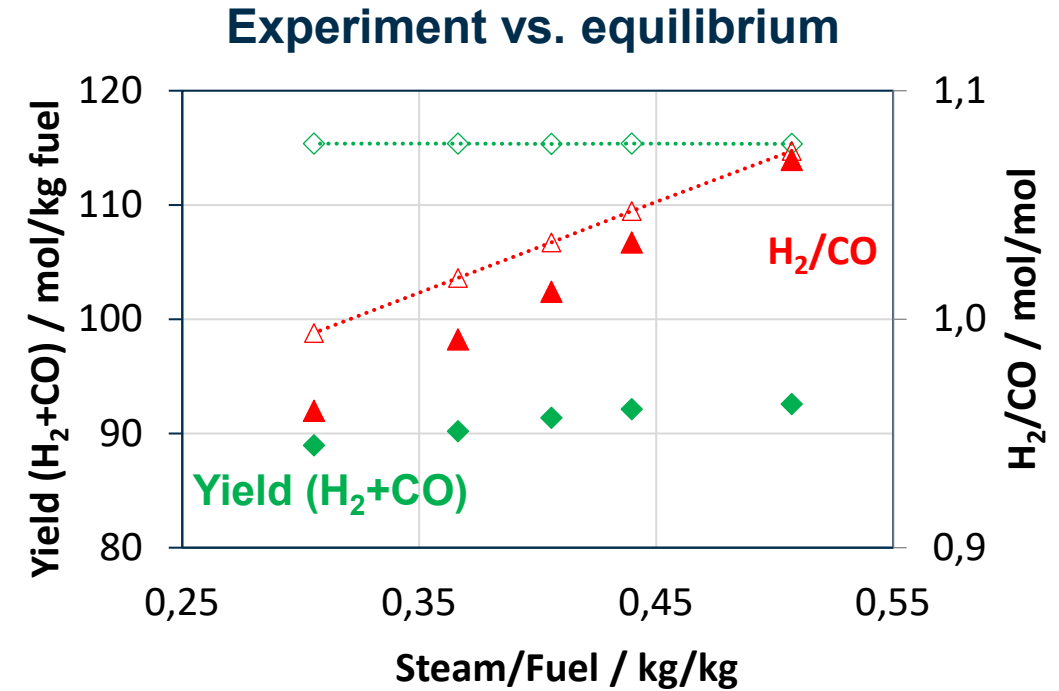
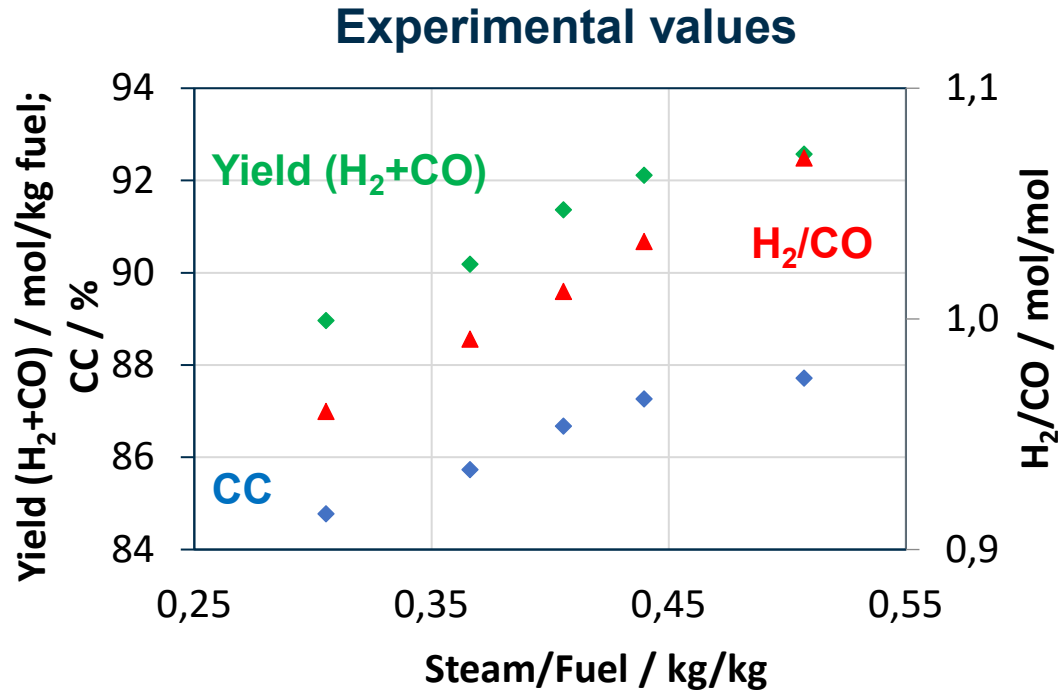


$\dot{M}_{\text{fuel}} = 8.6 \text{ kg/h}$
 $\lambda_{\text{tec}} = 0.45$
 $y_{\text{O}_2, \text{GM}} = 62.9 - 79.9 \text{ vol\%}$

Main syngas components:

- Steam addition influences
 - C/H ratio of product gas
 - oxidation rate of reactand mixture
- Shift of WGS: $\text{H}_2\text{O} + \text{CO} \rightarrow \text{H}_2 + \text{CO}_2$
- CH₄ reduced with steam addition if reaction temperature is constant
 → steam reforming: $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3 \text{H}_2$
- Temperature reduction due to steam addition not compensated → CH₄ increases

Influence of Steam on Characteristic Parameters



- Carbon conversion (CC), product gas yield and H₂/CO improved by steam addition
 - Steam reforming → increase in CO, H₂
 - Reaction of soot precursors and soot with steam
- Equilibrium values not reached due to incomplete conversion
 - Deviation decreases with increasing steam addition

$$\dot{M}_{\text{fuel}} = 8.6 \text{ kg/h}$$

$$\lambda_{\text{tec}} = 0.45$$

$$y_{\text{O}_2, \text{GM}} = 62.9 - 79.9 \text{ vol\%}$$

Summary / Conclusions

- Substitution of fossil fuels by renewable sources like biogenic or plastic waste based materials
 - increasing raw material sovereignty and closing carbon cycle
 - optimal operation of existing entrained flow gasifiers with new feedstock
- Experiments at high pressure entrained flow gasifier (40 bar, 5 MW) comparing biogenic and plastic waste based pyrolysis oil clearly showed the influence of heating value and carbon content on operation efficiency:
 - Existing gasifiers can be operated at higher load
 - Improved CGE and yield of H_2 and CO
- Detailed investigation on the influence of steam on fuel conversion under atmospheric entrained flow gasification conditions
 - Main syngas components depend on shift of WGS
 - Concentration of methane (and other intermediates) is mainly influenced by temperature dependent reactions like steam reforming.

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