Entrained flow Gasification of Biogenic Fuels: Influence of Process Parameters and Fuel Specification on Syngas Yield and Composition

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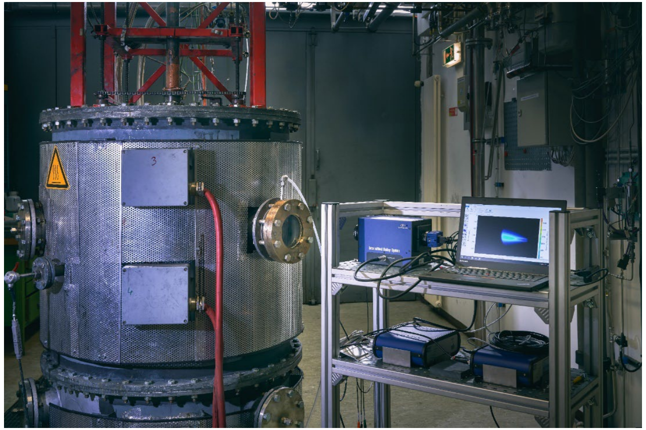
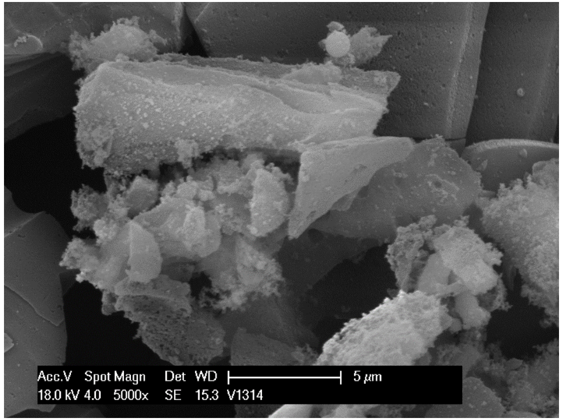
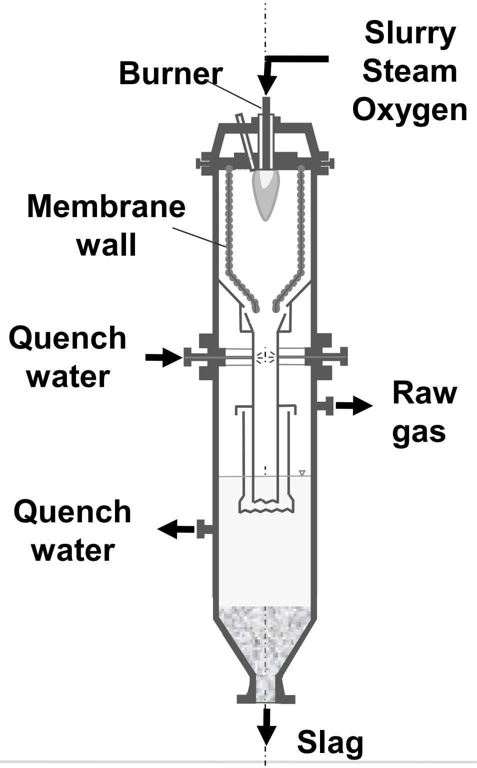




Introduction

High Pressure EFG



Goals

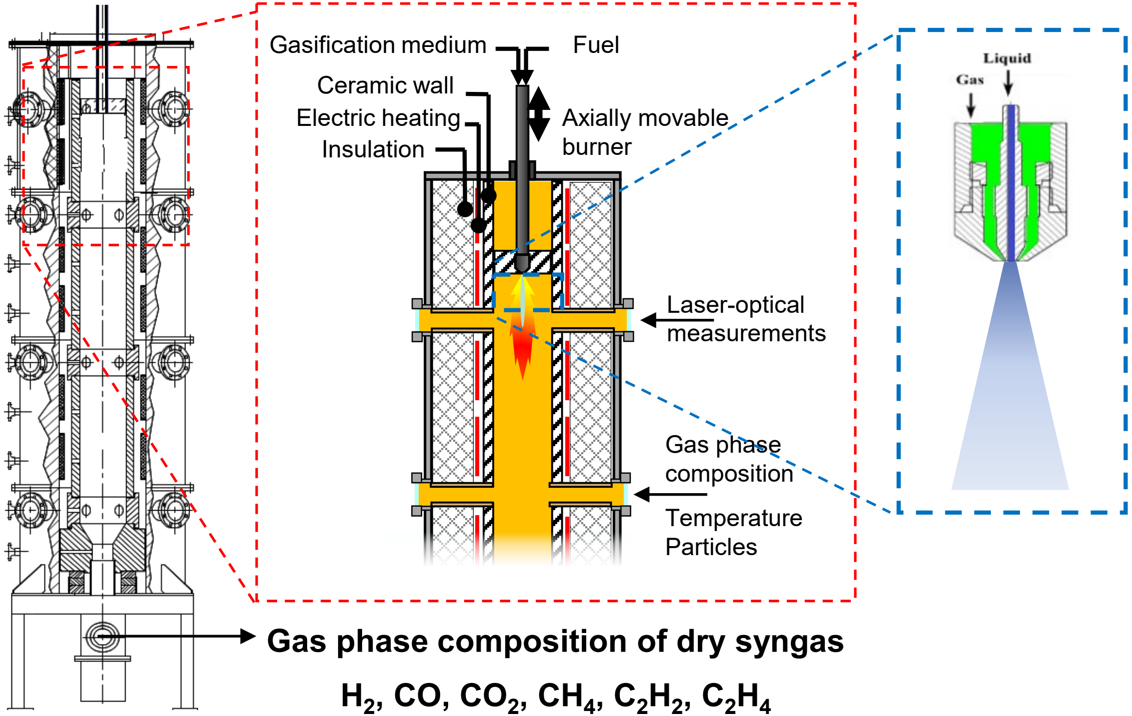
- High carbon conversion
- Maximum yield of CO and H_2
- Minimum amount of hydrocarbons, tar and soot

Energy and conversion efficiency coupled directly with process temperature

→Stoichiometry
→Fuel specification: heating value
catalytically active species

➔Evaluate the influence of temperature and fuel specification on syngas yield and composition

Research Entrained flow Gasifier REGA



Gas phase composition of dry syngas

H_2, CO, CO_2, CH_4, C_2H_2, C_2H_4

Technical data:

- Inner diameter: 0.28 m
- Length: 3 m
- Electric heating: 60 kW
- Max. wall temperature: 1200 °C
- Max. gas temperature: 1600 °C
- Pressure: 1 atm
- Liquid / suspension fuels: Fuel flow rate: max. 18 kg/h
- Gasification agent: O_2/N_2

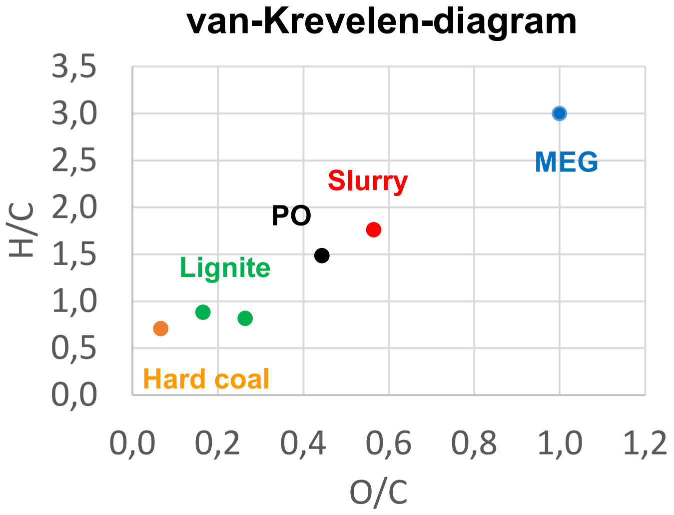
Fuel Specification

MEG: mono ethylene glycol → Liquid reference fuel

Slurry: MEG with 30 wt% beech wood char → Model suspension fuel

PO: pyrolysis oil from beech wood → Technical liquid fuel

	MEG $C_2H_6O_2$	Slurry $C_2H_{3,6}O_{1,2}$	PO $C_2H_3O_{0,8}$
H/C (molar)	3	1.8	1.5
O/C (molar)	1	0.6	0.4
LCV / MJ/kg	16.7	20.9	23.1
$O_{2\,min}$ / m^3 (STP) /kg	0.89	1.09	1.24



Design of Operating Conditions

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Evaluate influence of fuel specification and process temperature without variation of flow field

Reference point
MEG, Tad = 1700 °C

1. Vary fuel spec

Constant:
Tad = 1700 °C
u_{gas} = 159 m/s
V_{syngas} = 26 m³/h

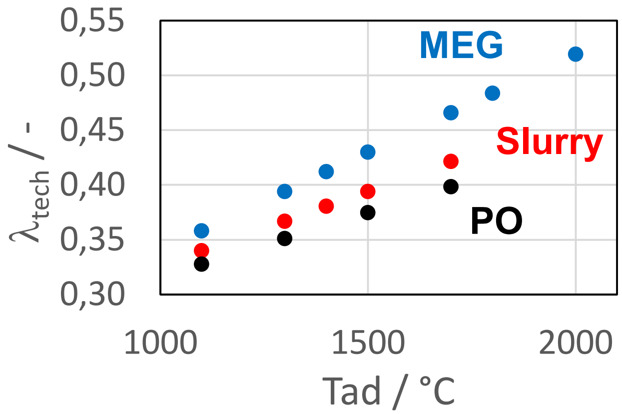
Slurry | **PO**

2. Vary Tad

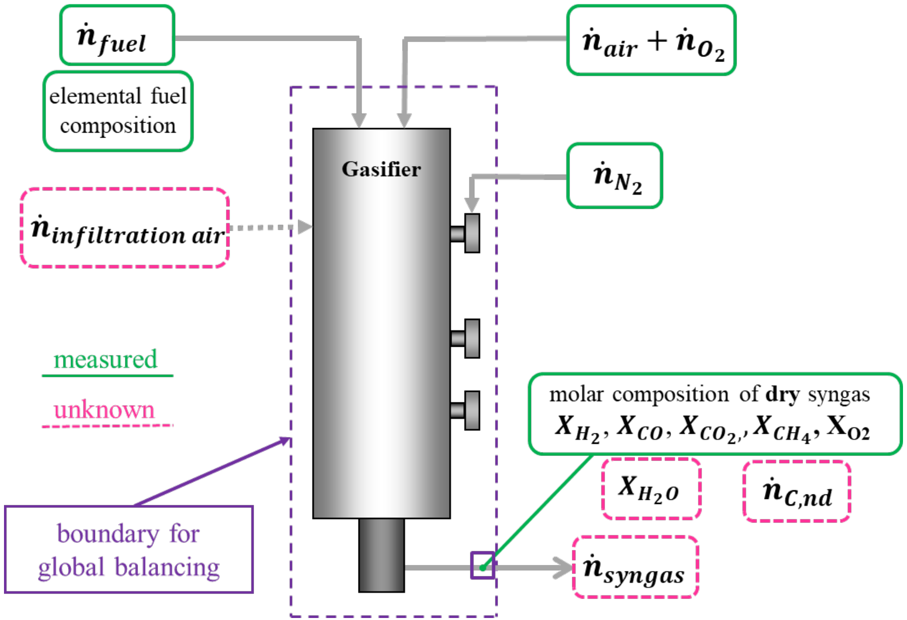
Constant:
u_{gas} = 159 m/s
V_{syngas} = 26 m^3/h

Change λ_{tech} and x_{O2}
(Aspen Design Spec)

MEG, Slurry, PO
Tad = 1100 to 2000 °C



Balancing / Characteristic Parameters



Assumptions:

N_2 inert

Cl, S completely to HCl, H_2S

Loss ($\dot{n}_{C,nd}$) with
H/C = 0.8 for MEG, PO1

H/C = 0 for Slurry

Elemental balancing: C, H, N, O

- **Unknown values**
- **Characteristic parameters:**

Carbon conversion:

$$CC_{fuel} = \frac{\dot{n}_{syngas} \cdot (X_{CO} + X_{CO2} + X_{CH4})}{\dot{n}_{c,fuel}}$$

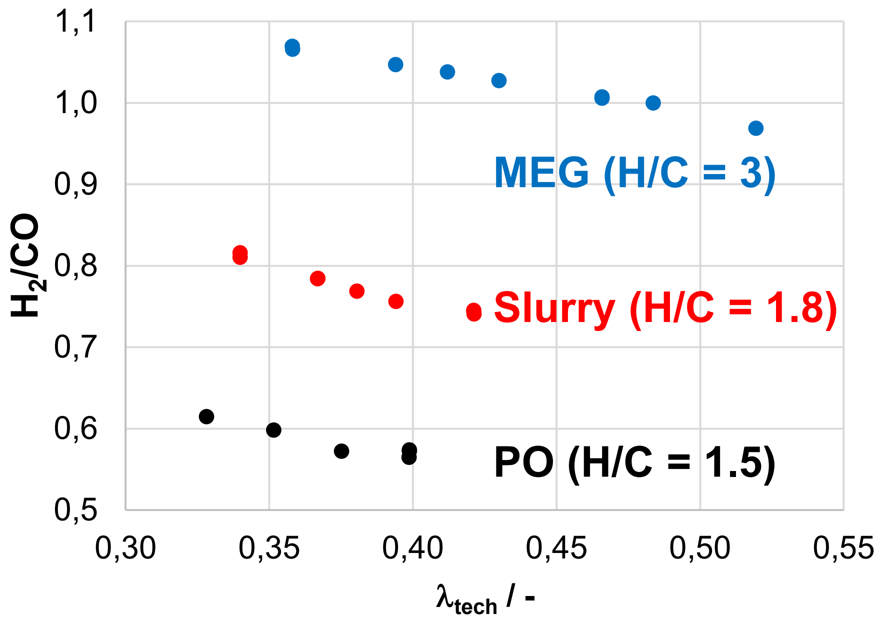
$$CC_{solid} = CC_{MEG} - \frac{CC_{MEG} - CC_{slurry}}{\dot{m}_{C,BC} / \dot{m}_{C,slurry}}$$

Yield (H_2+CO):

$$Yield(H2 + CO) = \frac{\dot{V}_{syngas} \cdot (X_{H2} + X_{CO})}{\dot{m}_{fuel}}$$

Syngas composition – ratio H_2/CO

H_2/CO as function of stoichiometry



H_2/CO increases with

- **H/C (fuel)**
- **decreasing stoichiometry**

→ Influence of fuel composition and process temperature

Syngas composition corresponds to partial water gas shift equilibrium:

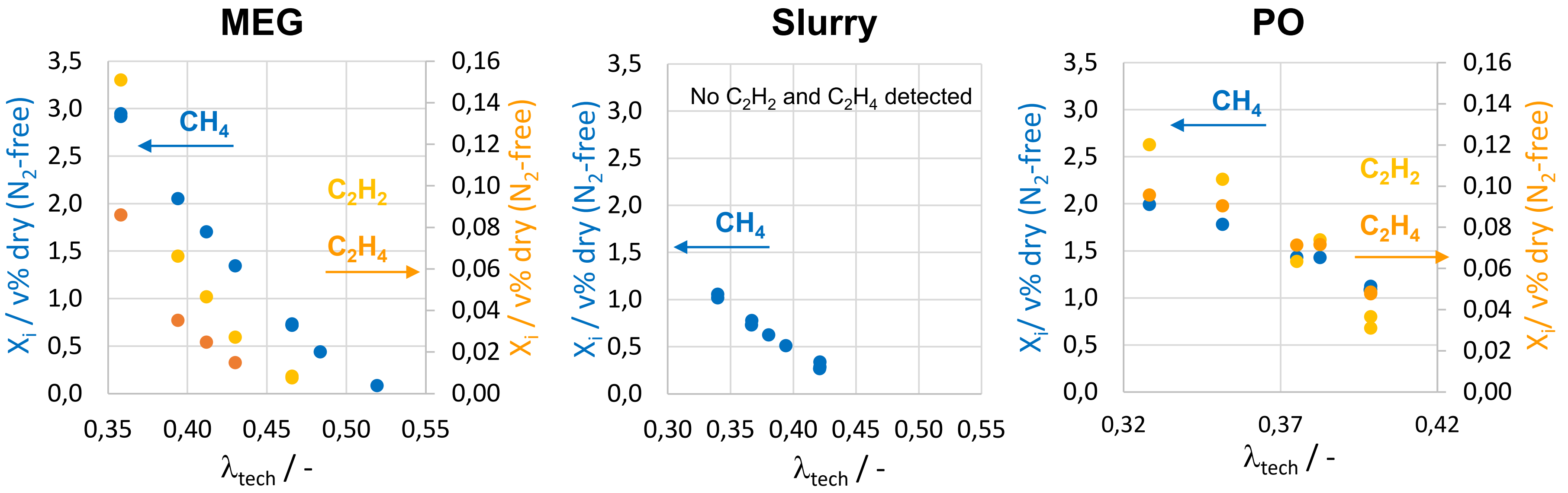
$$H_2 + CO_2 \leftrightarrows H_2O + CO$$

←

decrease in temperature

shift to (H_2 + CO_2)

Syngas composition – intermediates



- **Lower stoichiometry → increased content of intermediates due to temperature dependent slow gasification reaction kinetics → reduced degradation of intermediates**
- **Slurry: lower CH_4 content and no C2-HCs due to influence of catalytically active ash species**

Carbon Conversion

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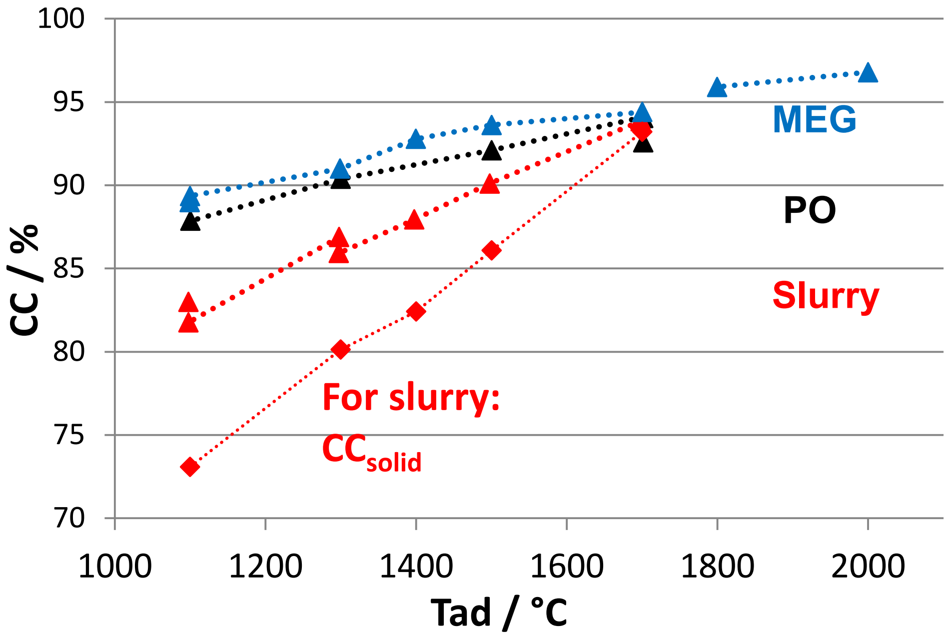
$$CC_{fuel} = \frac{\dot{n}_{syngas} \cdot (X_{CO} + X_{CO2} + X_{CH4})}{\dot{n}_{c,fuel}}$$

$$CC_{solid} = CC_{MEG} - \frac{CC_{MEG} - CC_{slurry}}{\dot{m}_{C,BC} / \dot{m}_{C,slurry}}$$



- **CC decreases with temperature for all fuels**
- **Curve progression similar for liquid fuels MEG and PO**
- **Reduction in CC more significant for slurry**

→ **Influence of temperature dependent gasification reaction kinetics**

Lower temperature results in

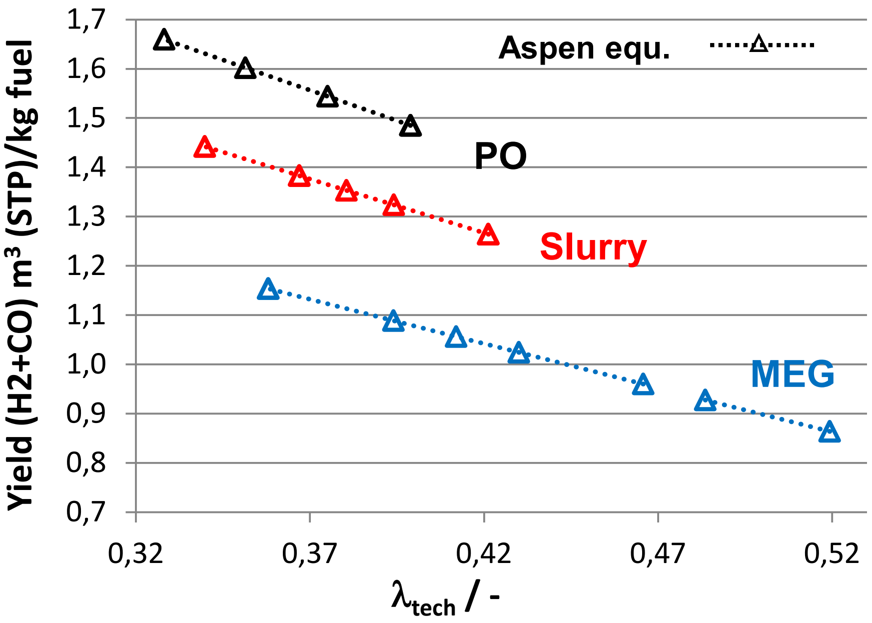
→ Reduced degredation of intermediates: C2-HCs, tar

→ Reduced conversion of solid component in slurry (char)

Yield of H_2 and CO

$$Yield(H2 + CO) = \frac{\dot{V}_{syngas} \cdot (X_{H2} + X_{CO})}{\dot{m}_{fuel}}$$

Yield (H2+CO) as function of stoichiometry
Aspen equilibrium values compared to experimental results



Equilibrium:

- **Maximum possible values**
- **linear increase with decreasing stoichiometry**
- **Yield PO > Slurry > MEG**

→ **Influence of fuel composition (C and H)**

→ **Influence of stoichiometry: lower oxidation state of reaction mixture at lower stoichiometry**

Yield of H_2 and CO

$$Yield(H2 + CO) = \frac{\dot{V}_{syngas} \cdot (X_{H2} + X_{CO})}{\dot{m}_{fuel}}$$

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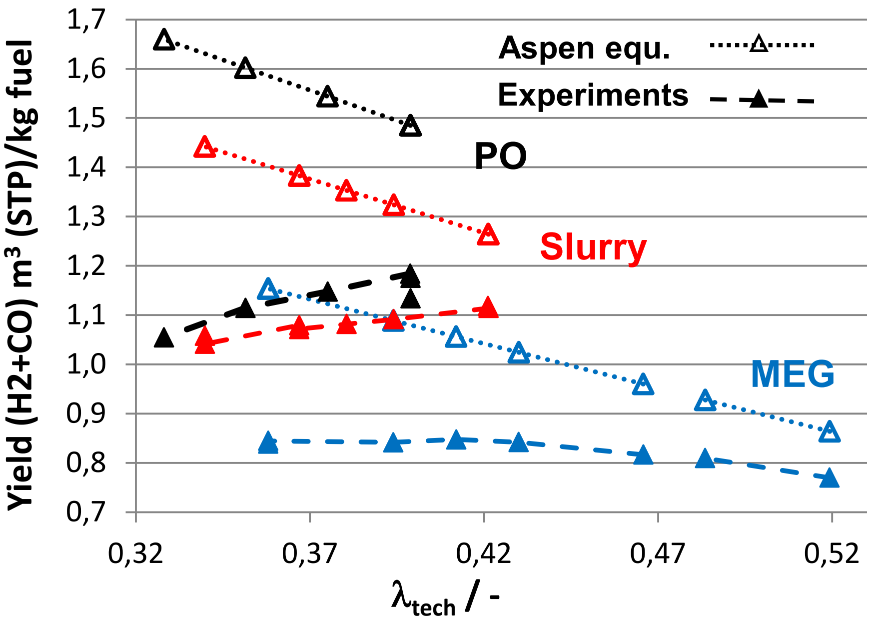
Yield (H2+CO) as function of stoichiometry
Aspen equilibrium values compared to experimental results



Experimental results

- **Deviation from equilibrium increases with decreasing stoichiometry**

→ **Influence of temperature dependent gasification reaction kinetics: reduced degradation of intermediates slow heterogeneous gasification reactions**

Summary and Outlook

Summary

- Influence of fuel specification and stoichiometry on syngas quality and yield evaluated under atmospheric entrained flow gasification conditions
- Major influence of temperature dependent gasification reaction kinetics on syngas composition and yield:
  - Heterogeneous gasification reactions → conversion of solid fuel components
  - Degradation of intermediates → CH_4, C2-HCs

Outlook

- Influence of the specification of the liquid phase on fuel conversion?
- Influence of solid content and solid particle size on fuel conversion?
- Characterization of flame zone applying laser-optical measurements

Thank you for your attention!