

**WORKSHOP:
“From Idea to commercialization with Horizon Europe projects”**

From Material Discovery to Demonstration Scale



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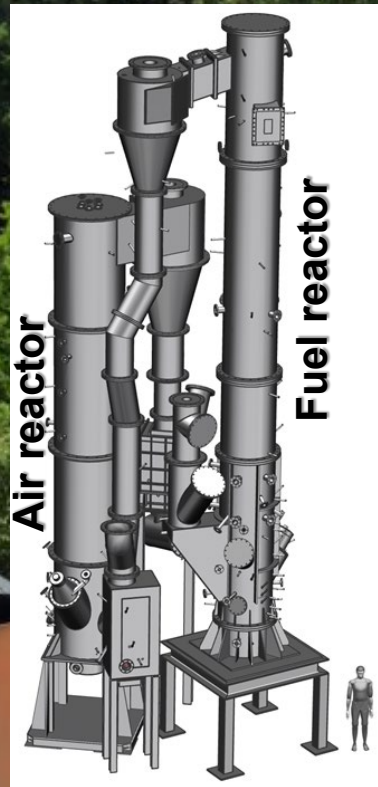


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the European Union**

1 MW CL pilot unit



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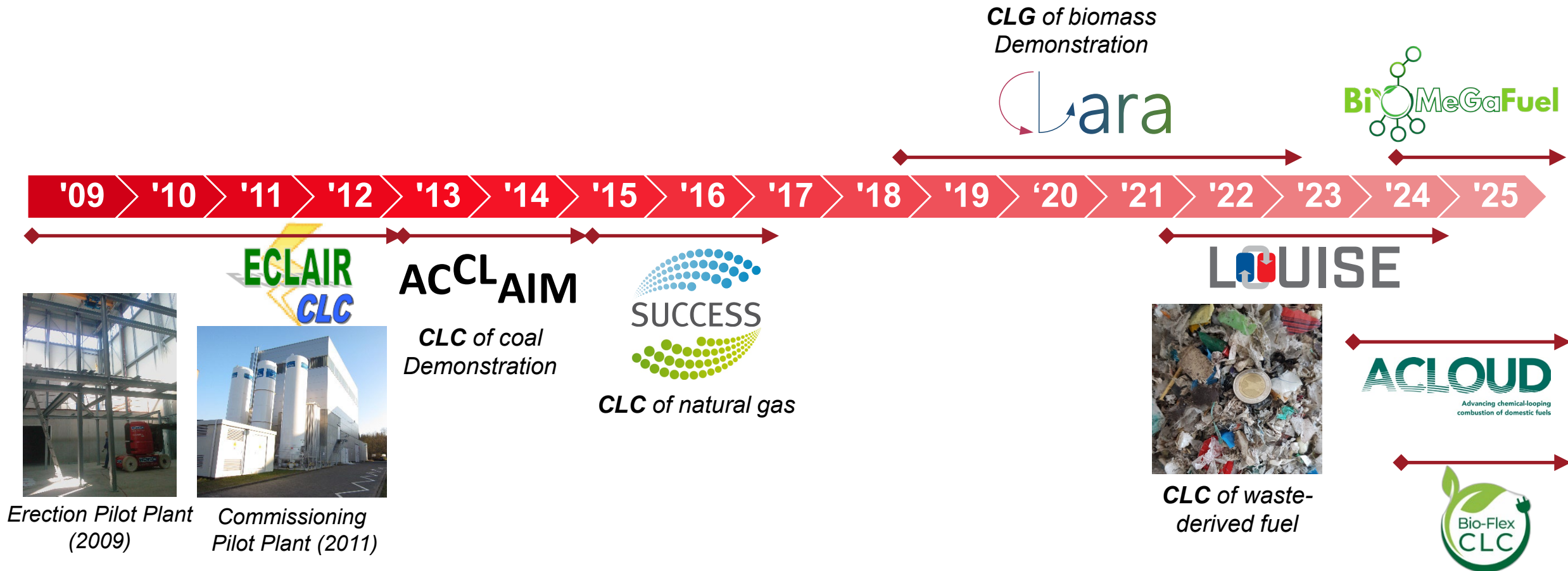


Laboratories

**Gas cleaning plant
(gasification)**

Synthesis test rig

CL – Projects



CL – State of the Art

- Technology demonstrated at pilot scale

- 1 MW_{th} in Darmstadt
- 5 MW_{th} in China

- Oxygen carriers (natural ores)

- Ilmenite (Fe-Ti-oxide)
- Iron ore

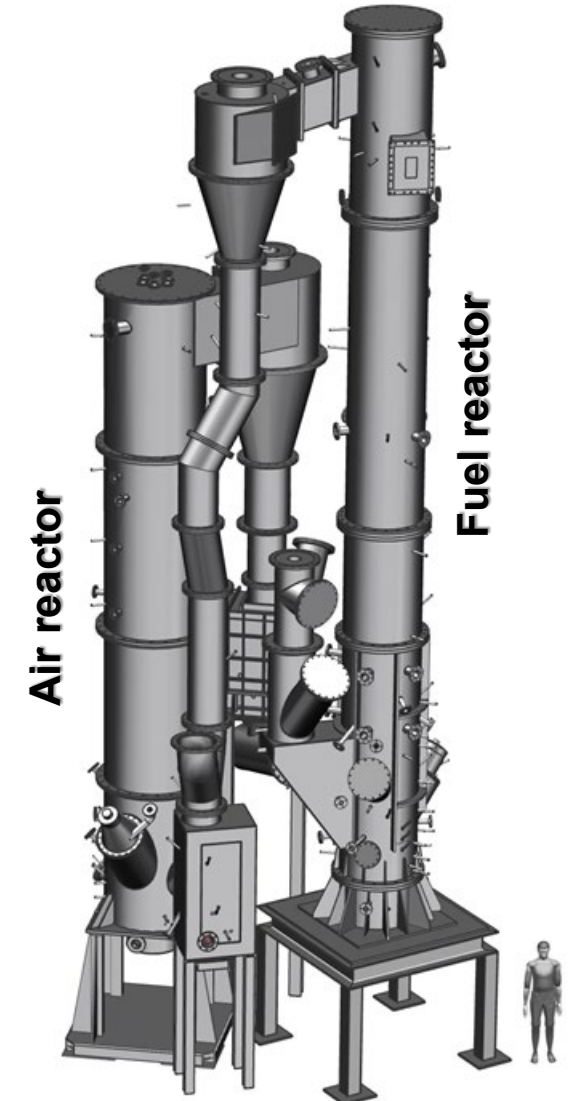
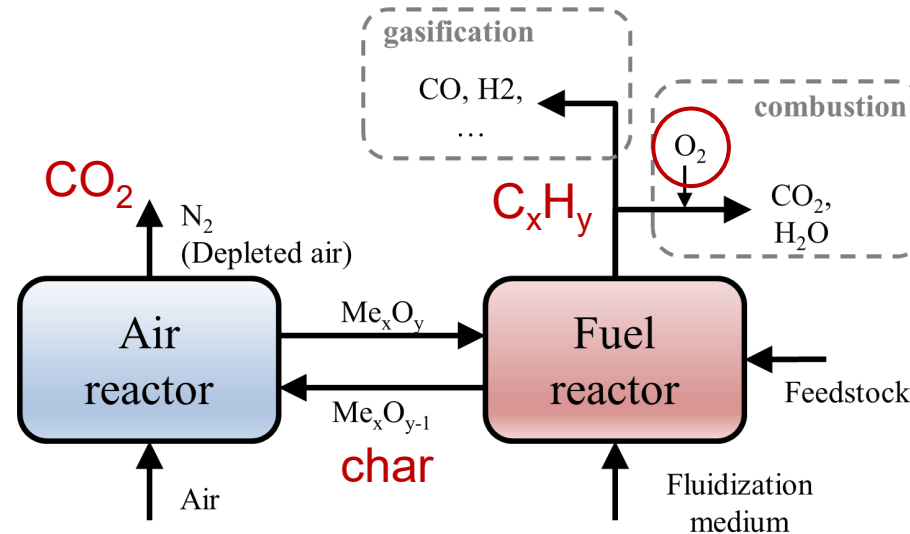
- Various fuels:

- Natural gas
- Hard coal
- Lignite
- Biomass
- Waste/SRF

Major challenges

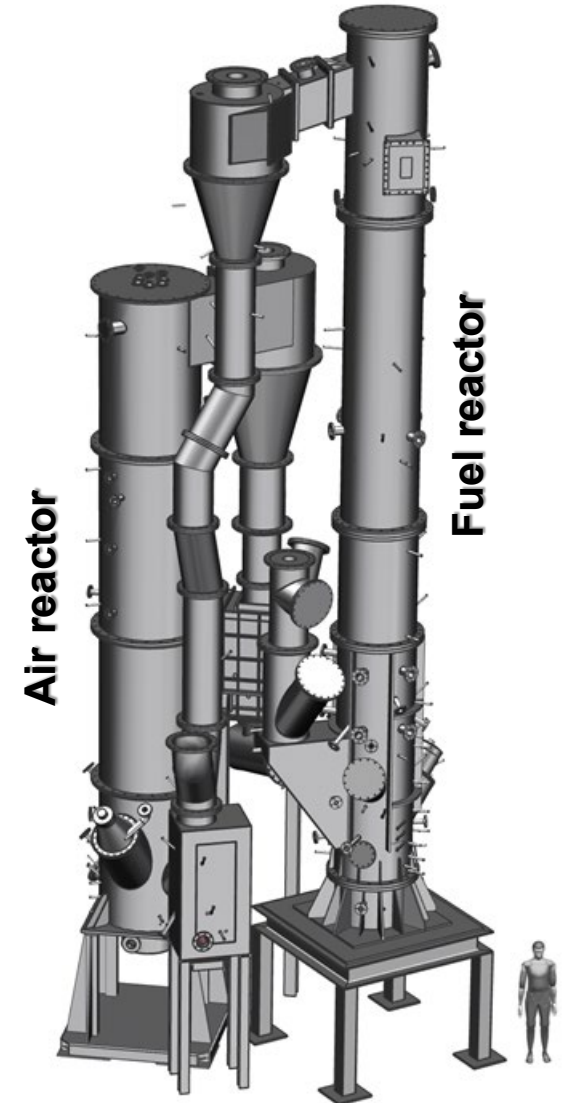
Conversion of char

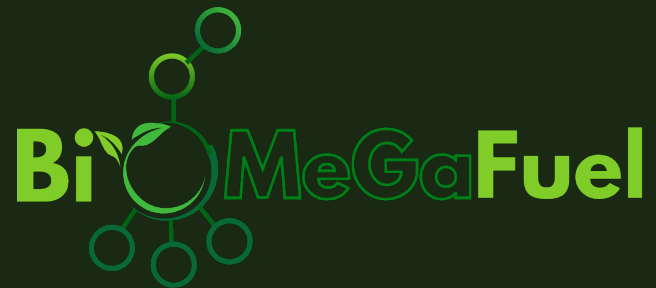
Conversion of volatiles (e.g. hydrocarbons)



CL – Experience

- Chemical looping with biomass & waste **demonstrated** at 1 MW_{th} scale
- Rather high **carbon capture** efficiency
- High **hydrocarbons yield**
 - CLC: high oxygen demand
 - CLG: reforming required
- **Reduction** of hydrocarbon yield desired
 - Increase temperature (higher circulation)
 - Improve gas-solid contact (reactor design)
 - More reactive oxygen carrier





Bio Methanol Production via Chemical Looping Gasification Coupled with
Membrane Reactors

Chemical looping gasification at 1 MW scale



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Objectives



- ❖ To validate autothermal chemical looping gasification of biogenic residues in an industrially relevant environment at 1 MW_{th} scale for more than 100 hours
- ❖ To compare CLG with HTW as the benchmark gasification technology



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HTW[®] experiments at 500 kW_{th} pilot plant



❖ Objectives

- ❖ Provide experimental data on the state-of-the-art gasification technology
 - ❖ for comparison with CLG (same feedstock)
 - ❖ for Validation 1-D HTW[®] model

❖ Status:

- ❖ Experimental campaign completed (Aug 2025)
- ❖ Analyses completed



500 kW_{th} HTW[®] pilot plant at TUDA



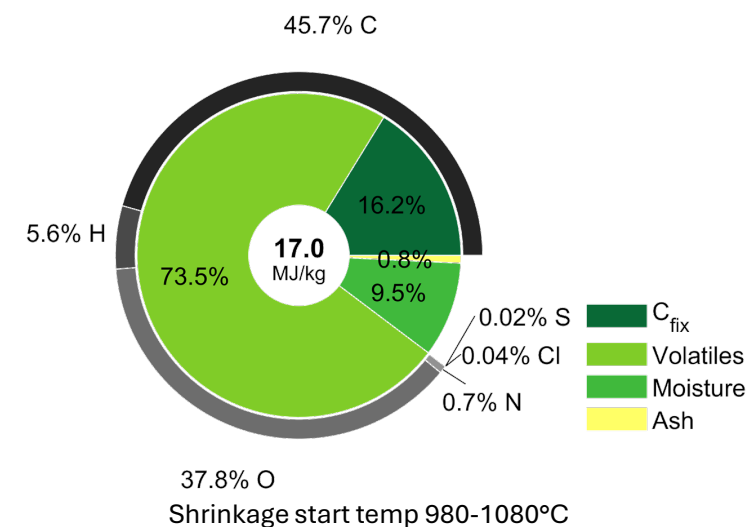
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HTW[®] experiments at 500 kWth pilot plant



Waste Wood Pellets



❖ Experimental plan

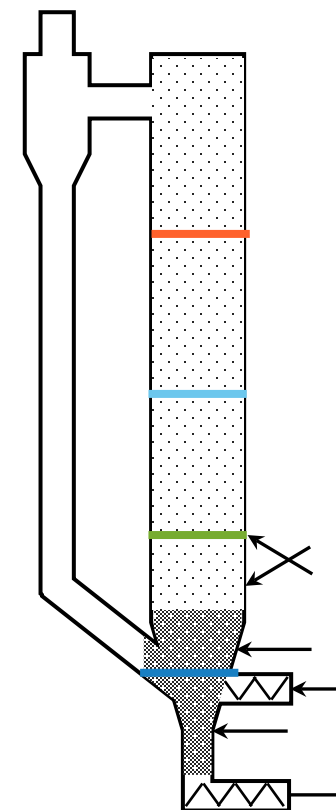
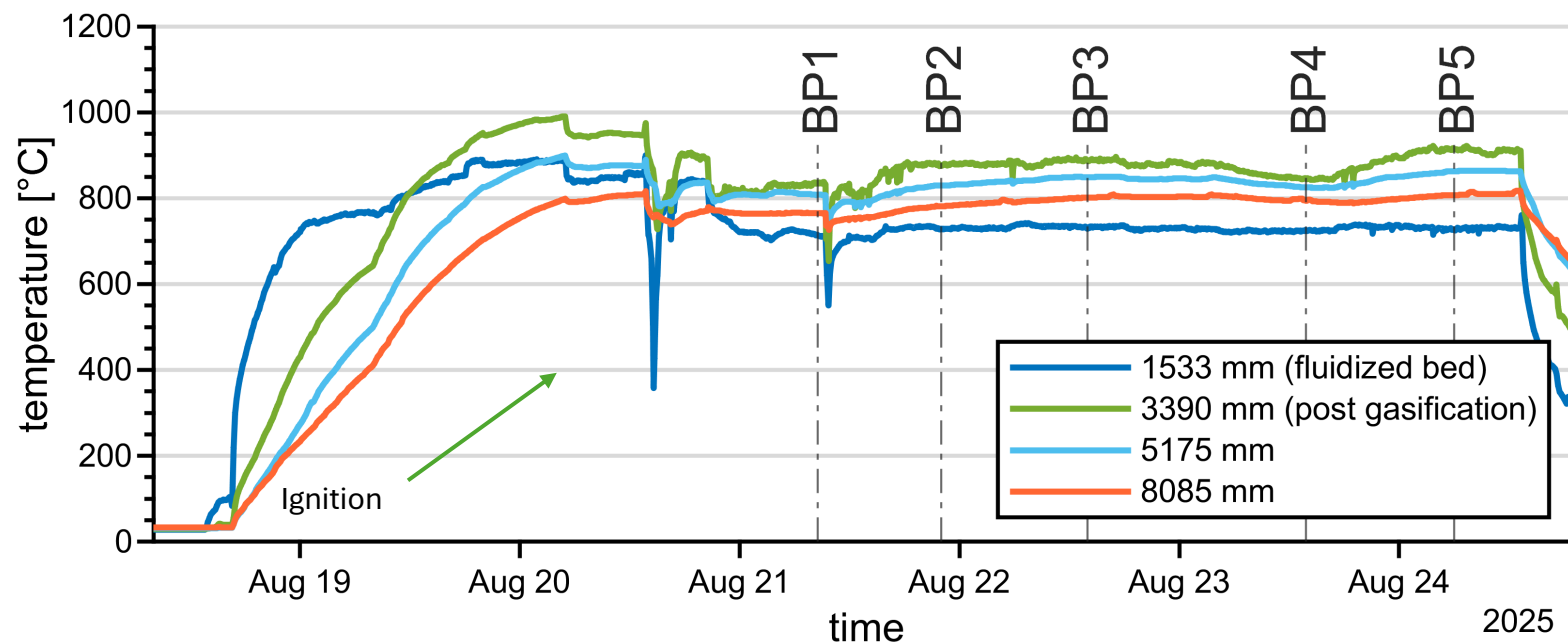
Stable operation

Variation of
lambda

Variation of S/B

Different
temperature

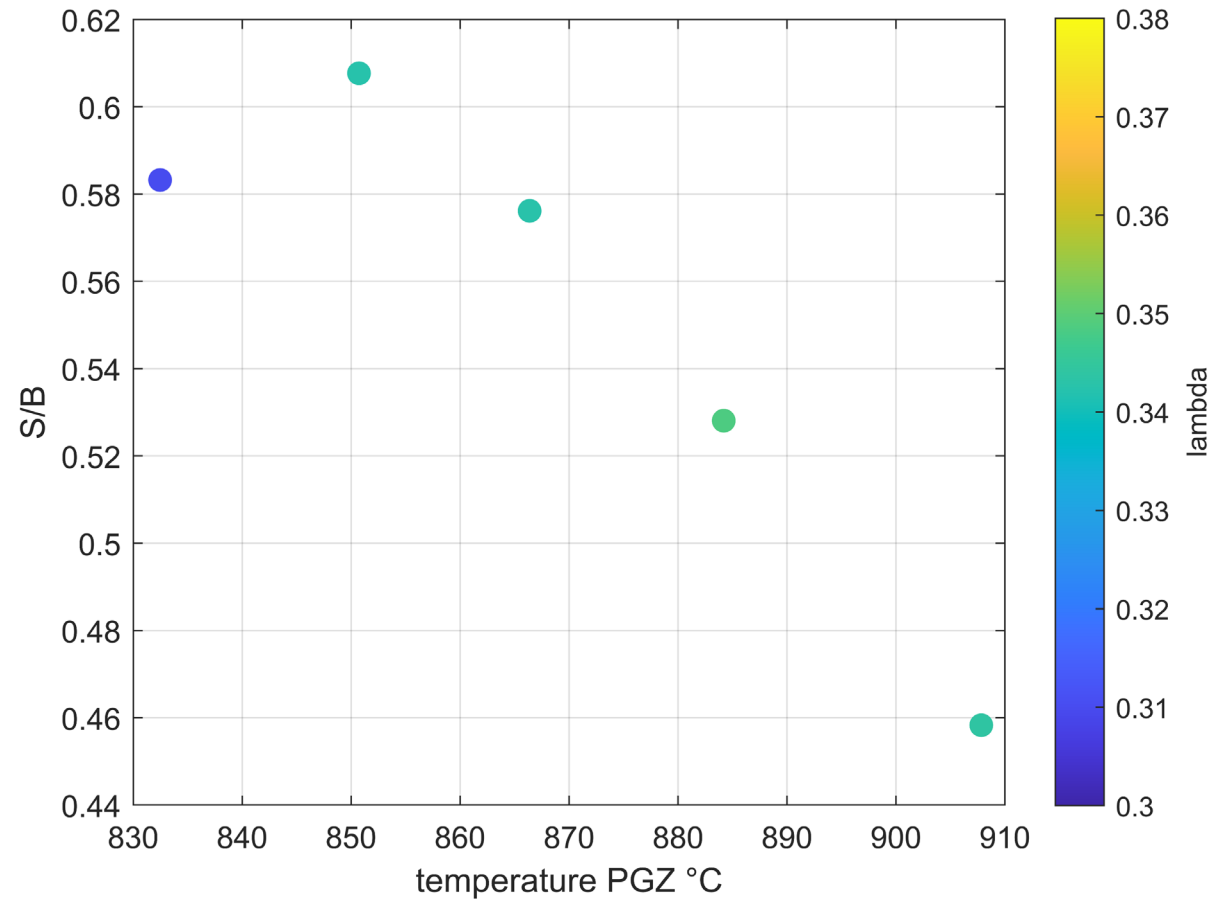
HTW[®] experiments at 500 kWth pilot plant





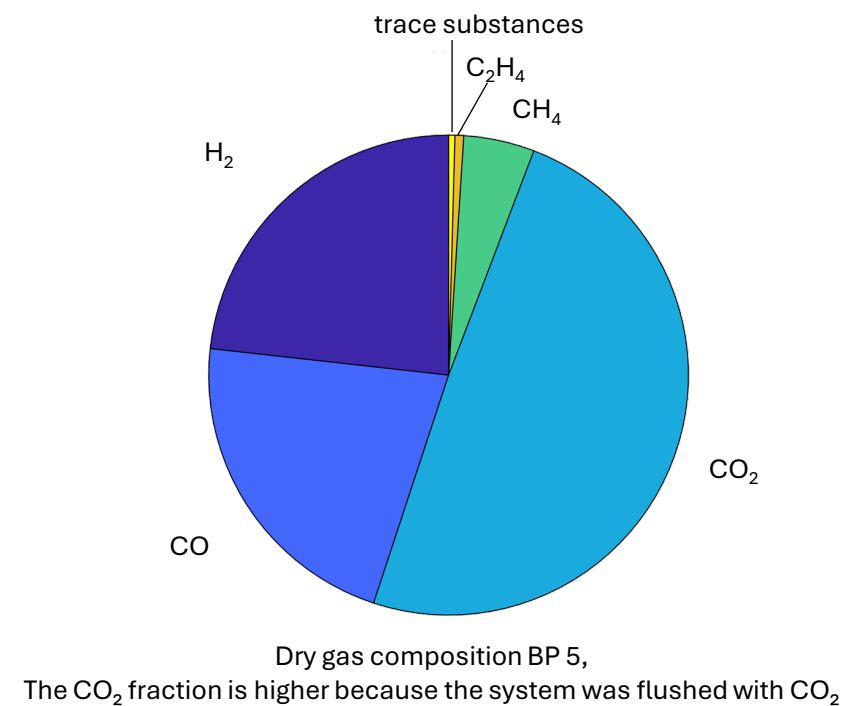
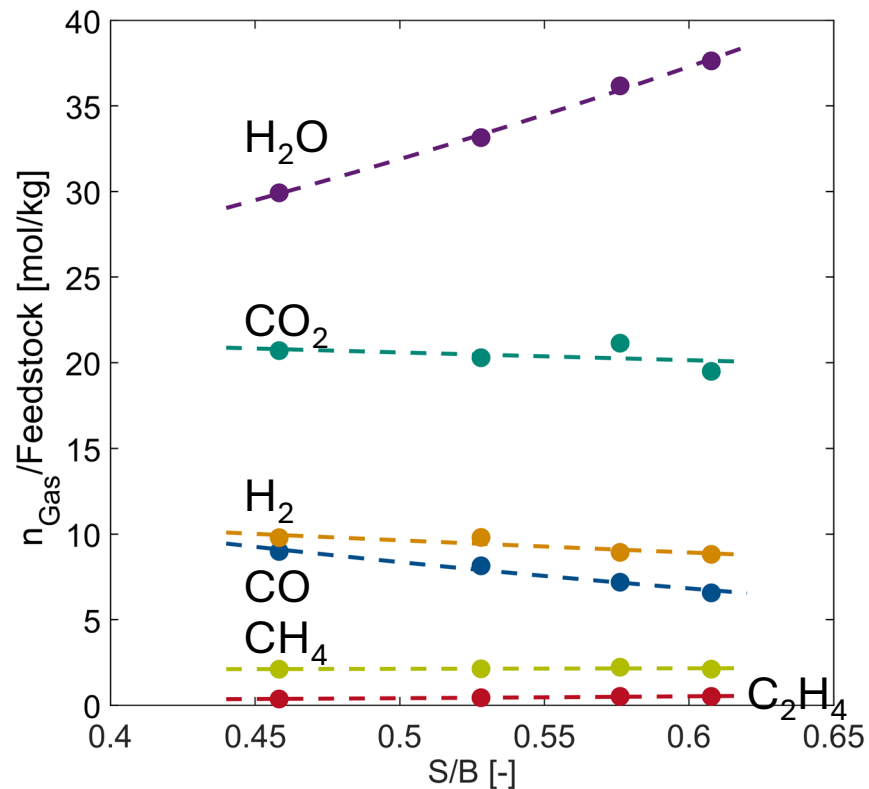
HTW[®] experiments at 500 kWth pilot plant

Influence of S/B



HTW[®] experiments at 500 kWth pilot plant

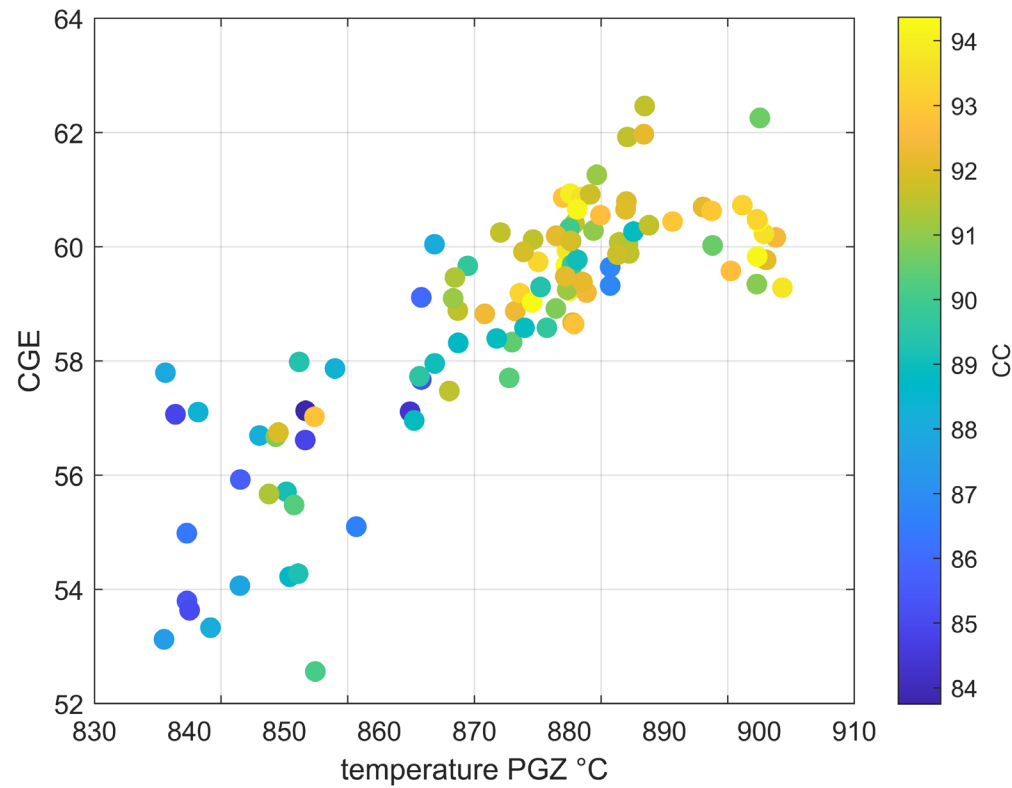
Gas composition



The CO₂ normalized concentration still contains purge gases.

HTW[®] experiments at 500 kWth pilot plant

Influence of Temperature on CGE

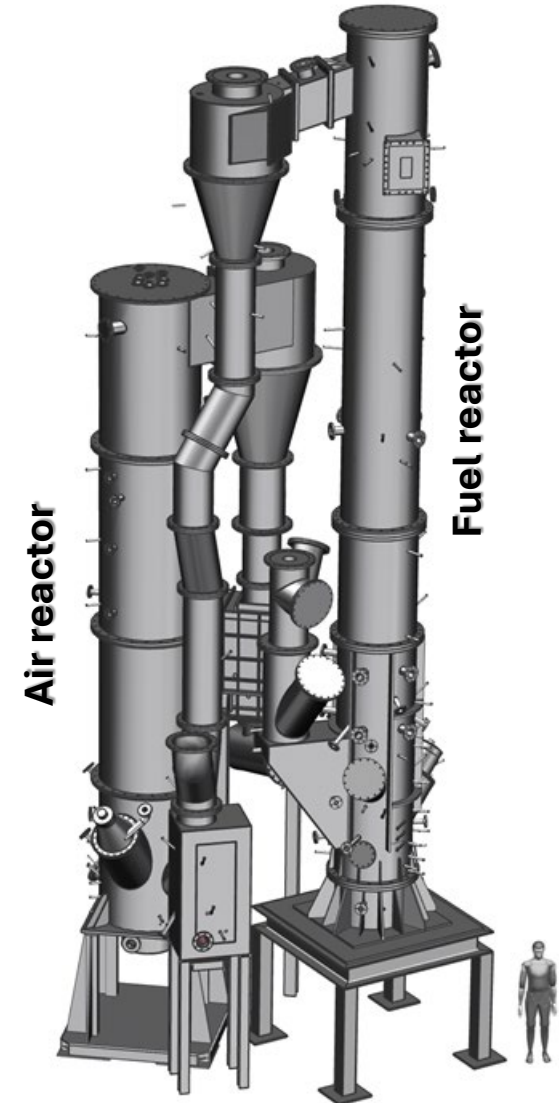


Lower CGE than in commercial plant due to higher heat loss

CLG experiments at 1 MWth pilot plant



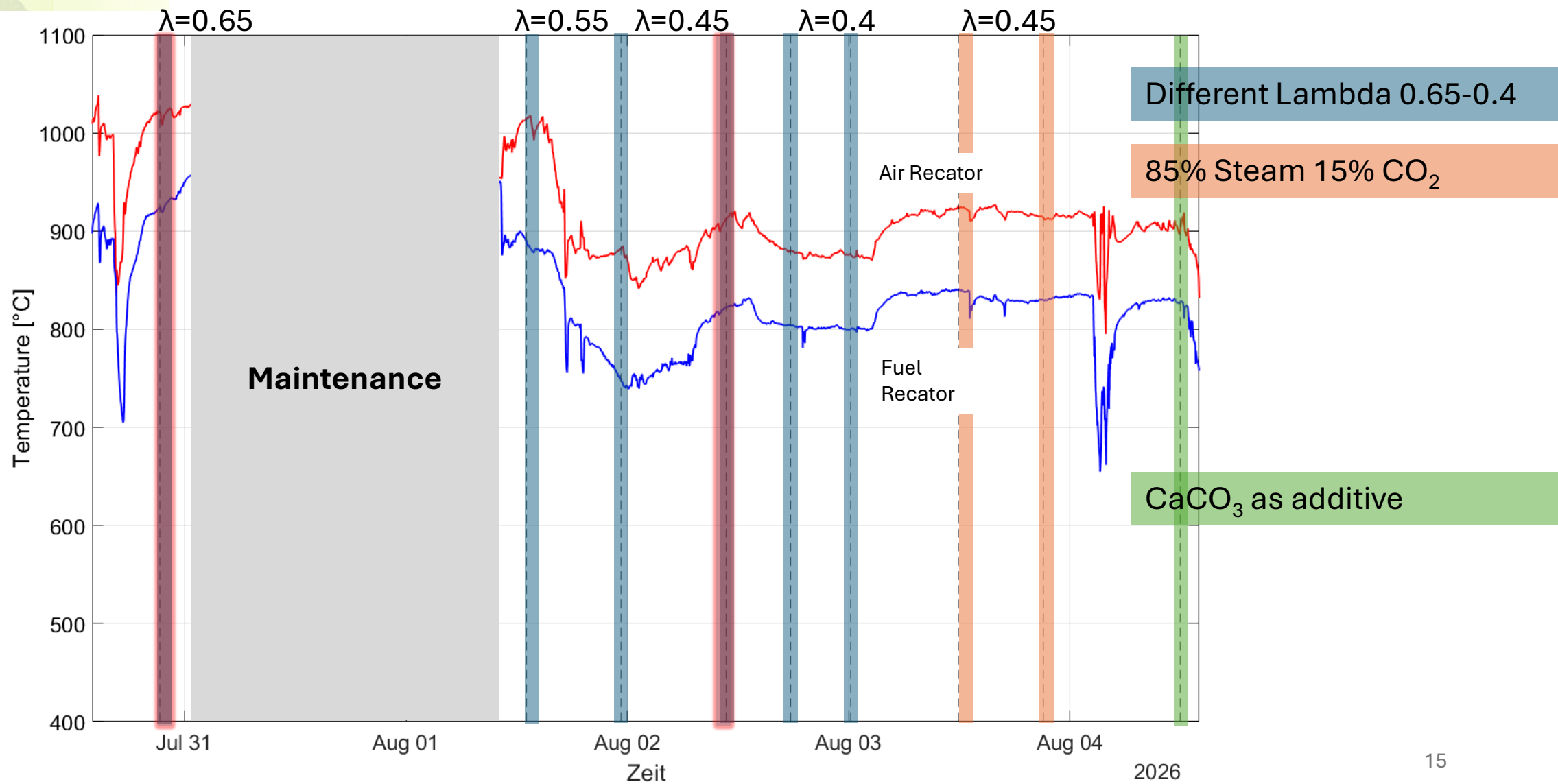
- ❖ CLG of waste wood (with increased circulation)
 - ❖ λ 0.4 – 0.7
 - ❖ T_{FR} 800 – 950 °C
 - ❖ 110 h autothermal operation
 - ❖ 60 h gas cleaning
- ❖ Status:
 - ❖ Experimental campaign completed (Aug 2026)
 - ❖ Analyses ongoing



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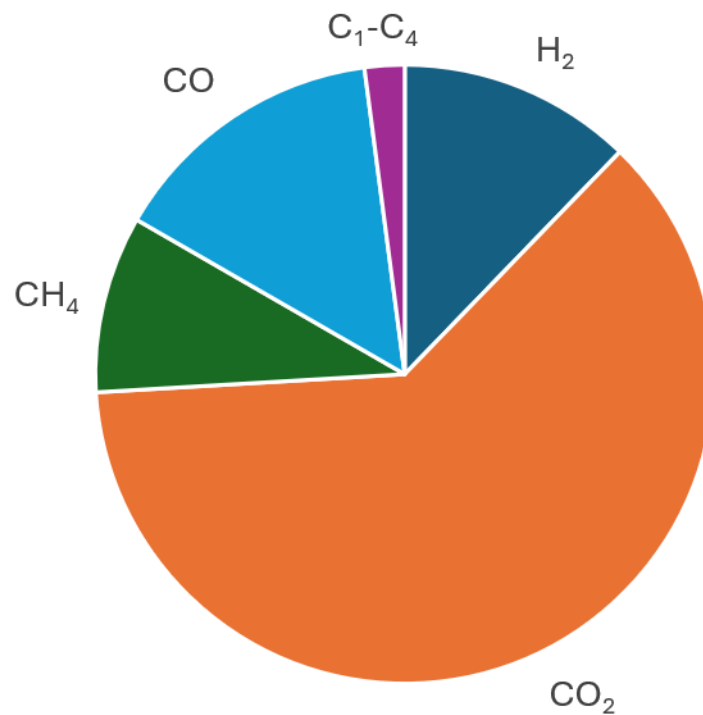
CLG experiments at 1 MWth pilot plant



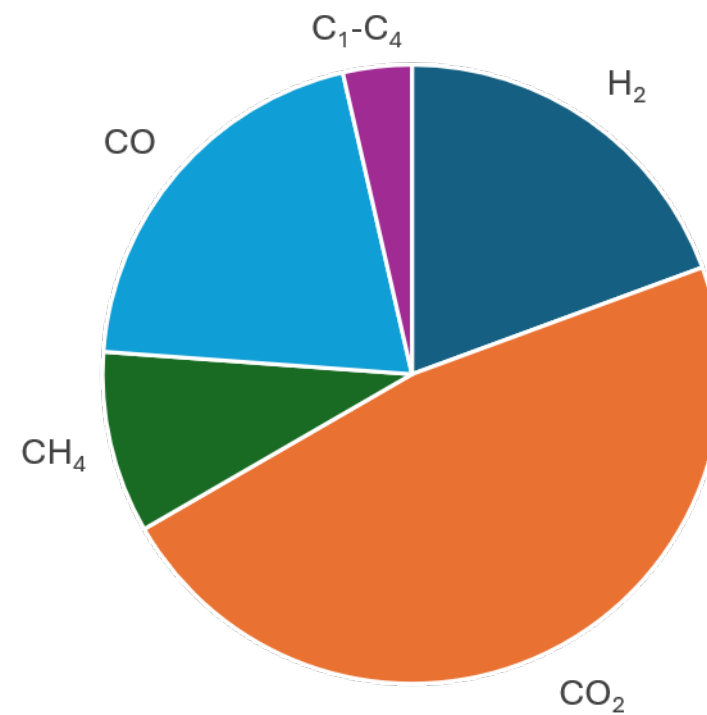
CLG experiments at 1 MWth pilot plant



$\lambda = 0.65$



$\lambda = 0.45$



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Flexible chemical looping combustion for combined heat and power
production from biogenic residues with negative emission

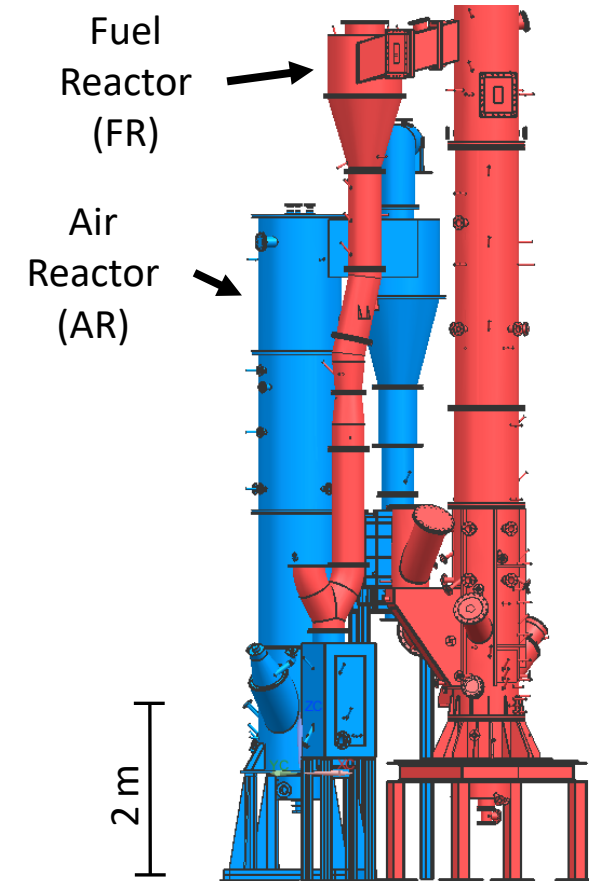
Demonstration of Bio-FlexCLC at 1 MW scale

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Objectives

- Demonstrate the feasibility of a **flexible CFB-CLC unit** at MW scale
- Demonstrate the **fuel flexibility** of a Bio-FlexCLC unit
- Enable full conversion of gases in **post-oxidation chamber** at minimum O₂ excess ($\lambda < 1.1$)
- Quantify the **process performance** of a Bio-FlexCLC unit
- Determine the **corrosion** and **fouling** rate at heat exchanger surfaces of a Bio-FlexCLC unit
- Quantify SO_x, NO_x, and particle **emissions** from a Bio-FlexCLC unit
- Quantify **agglomeration** and **attrition** in a Bio-FlexCLC unit

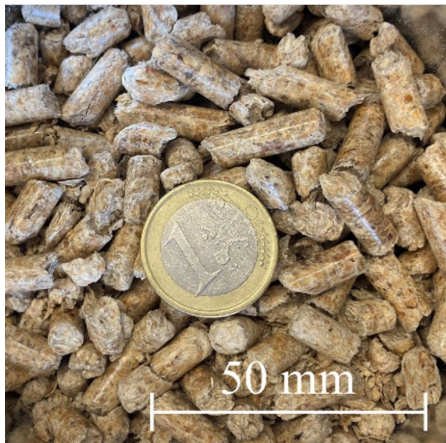


Demonstration of flexible Bio-CLC plant at 1 MW_{th} scale with various biomasses



- perform test campaigns
 - duration: 4 weeks (2 x 2 weeks), 24 h/d
 - a. operation of a flexible CFB-CLC unit
 - switch modes CFB - CLC
 - fuel flexibility
 - b. FR is filled with packings
 - evaluate its effect
 - measure gas composition
- determine process performance
- determine POC performance

Fuels & oxygen carrier @TUDA



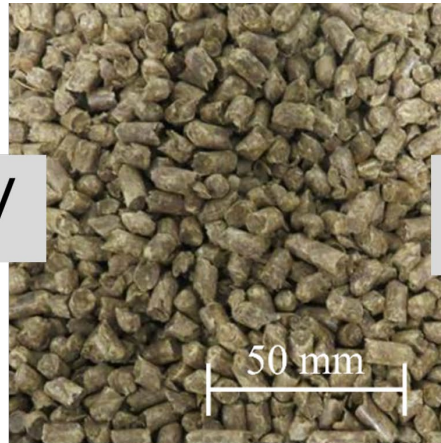
Commercial wood pellets

- spruce/pine
- diameter 6 mm pellets
- heating up



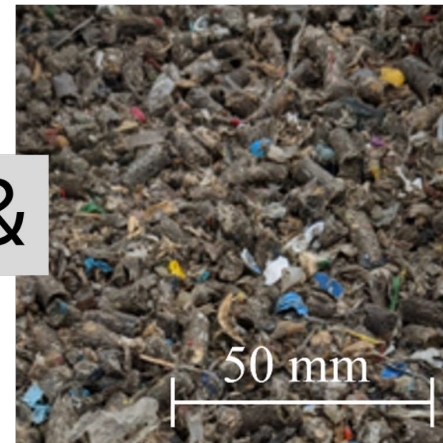
Tops and branches wood chips (local supplier)

- spruce
- 0 – 10 mm



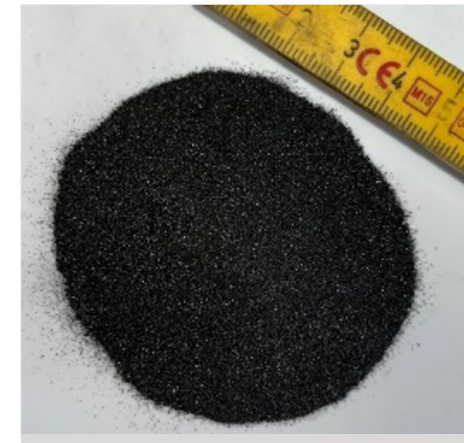
Tops and branches pellets (Torkapparater)

- spruce
- diameter 6 mm



RDF pellets (N+P)

- diameter 6 mm

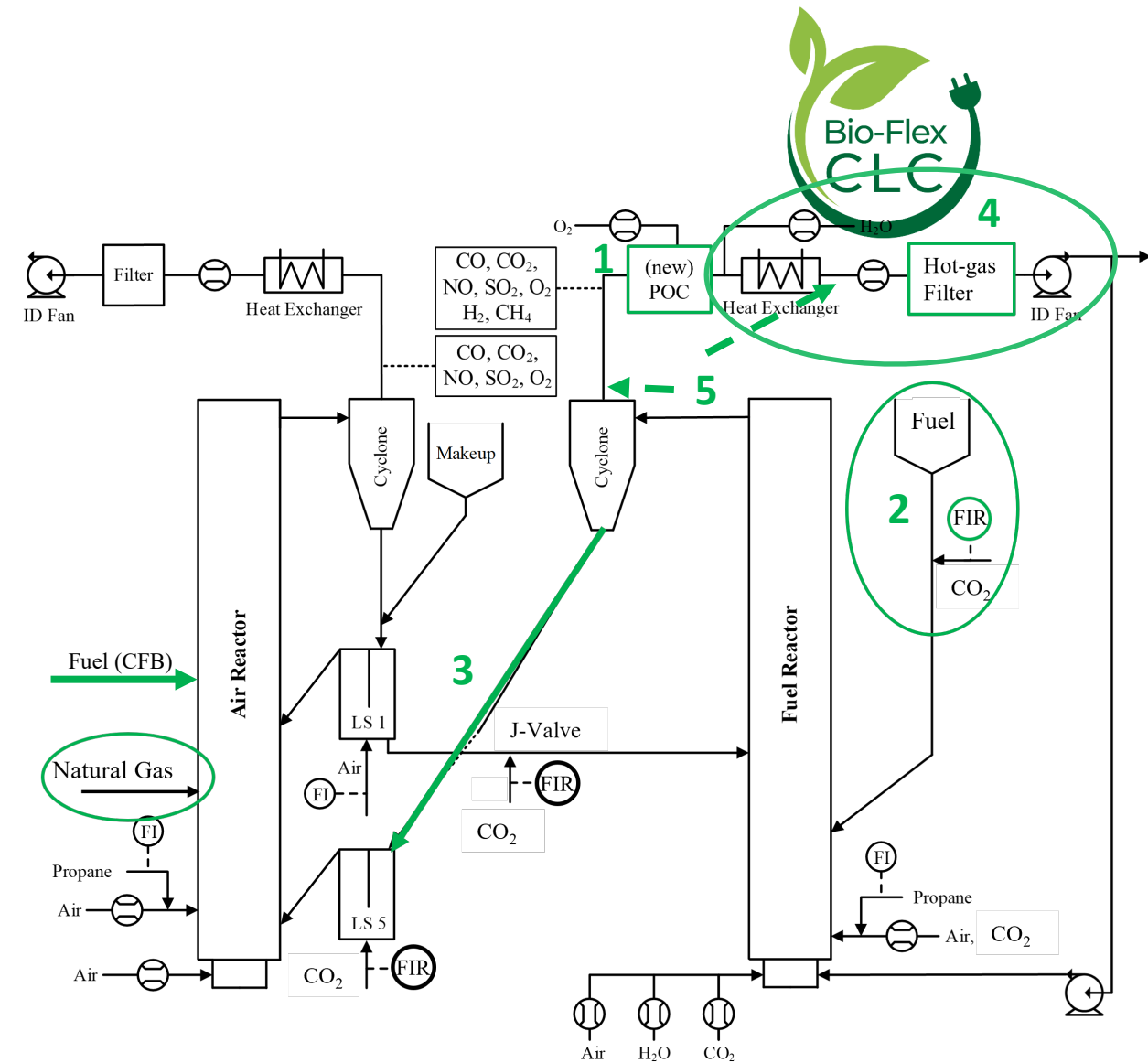


Ilmenite (fine)

- delivered (24 t)
- drying in CFB bed was carried out
- production of two fractions
 - coarse (reference)
d50 ~ 130 μ m ~ 14 t
 - fine
d50 ~ 70 μ m ~ 5 t
- further analysis is carried out

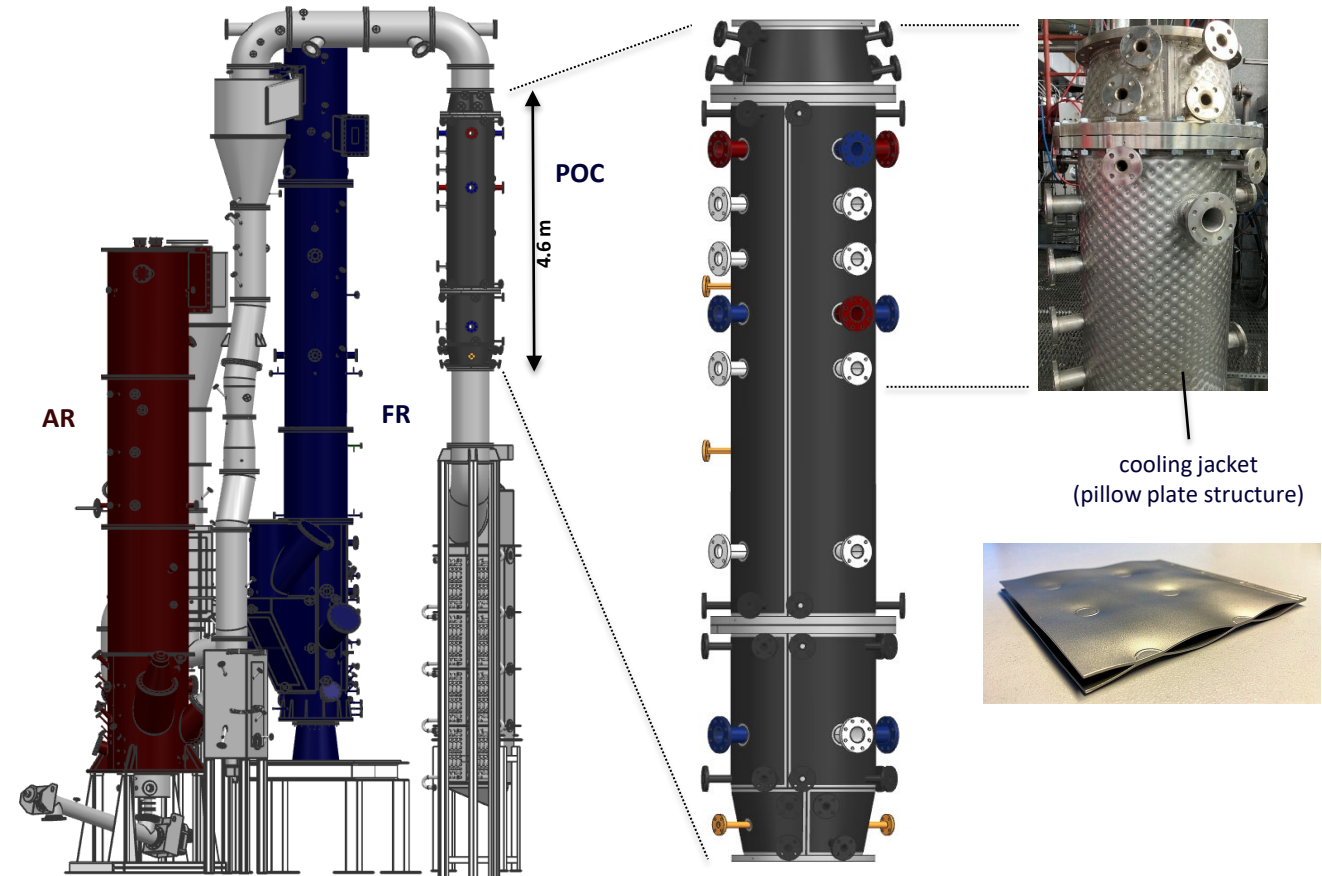
Adaptions of pilot plant

	Component
1	Post oxidation chamber (POC)
2	Fuel feeding system
3	Standpipe FR
4	New piping to enable flue gas recirculation
5	Gas sampling downstream FR



Post-oxidation chamber (POC)

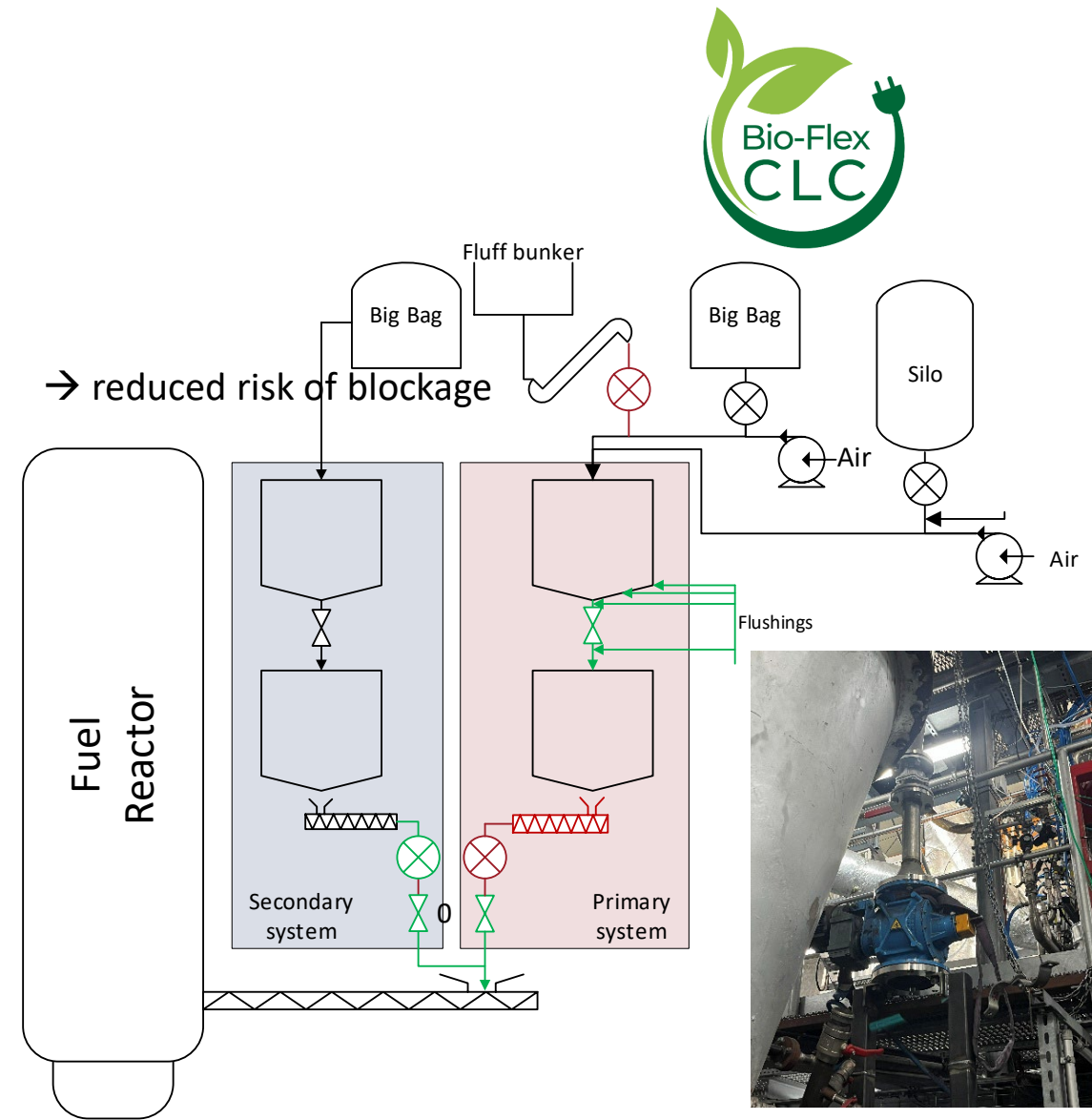
- **Combustion:** 600 kW by O₂ injection (2 stages)
- **Cooling:** wall (pillow plates), quench
- **Measurement:** 10 positions for measurements



Fuel feeding system

Improvements

- increase diameter (piping, slider, rotary valve, dosing screw)
- new flushings, vibrating elements
- decoupling primary & secondary system
- CO₂ flow measurements



Packings

CHALMERS

- **RMSR 25-3**, stainless steel (Hansa Engineering Group)



- void fraction: 97 (– 98) %
- nominal size: 40 (40, 50, 60, 70) mm

- **Hiflow ring 25-5**, stainless steel



- void fraction: 95 (– 98) %
- nominal size: 25 (28, 38, 40, 50, 110) mm

TUDA

- Selection pending (based on WP2)
- FR 400 mm inner diameter, refractory lining, reactor nozzle base plate, bottom product discharge
← feasibility check

Gas treatment and liquefaction



TB12 (RISE)

- 20-foot high-cube sea container
 - 12 m length!
- 10 Nm³/h process capacity
- SRC (NH₃)
 - installation after id. fan preferred

induced draft fan



hot gas filter



forklift operating area

space for TB12

gas cleaning plant

gas cylinder cage



Fouling and corrosion assessment of 1 MW flexible Bio-CLC operation



- insert corrosion probes into off-gas
 - AR & FR (during T4.2)
- effect of operating conditions on corrosion signal
 - CFB / CLC mode, fuel type, presence of packings
- analyse electrodes to determine
 - a. total weight loss → corrosion rate
 - b. metal phases → corrosion mechanisms
 - c. composition of ash deposits → fouling mechanisms
- define maximum steam temperatures
 - select materials for heat exchangers
 - develop mitigation strategies for corrosion/fouling



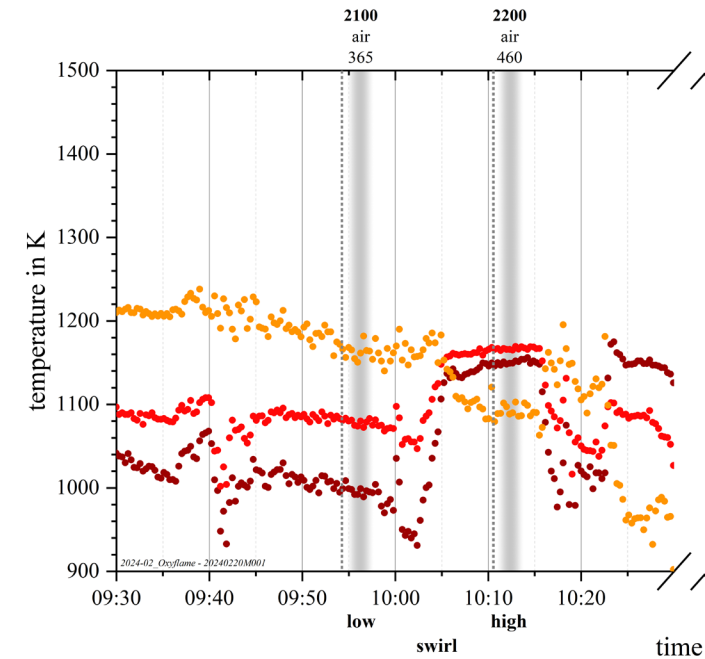
Agglomeration and attrition of bed materials and particle emission

- take solid samples (during T4.2)
 - fuel, bed material, ash from filters
 - various positions
 - measure accumulated particle mass
 - determine the PSD
 - quantify agglomeration and attrition
 - evaluate efficiency of particle separators
- define measures for avoiding agglomeration
- maximum bed temperatures or additives to fuels
 - measures to minimize particle loss and emissions



Investigation of the fate of SO_x and NO_x in the flexible operation

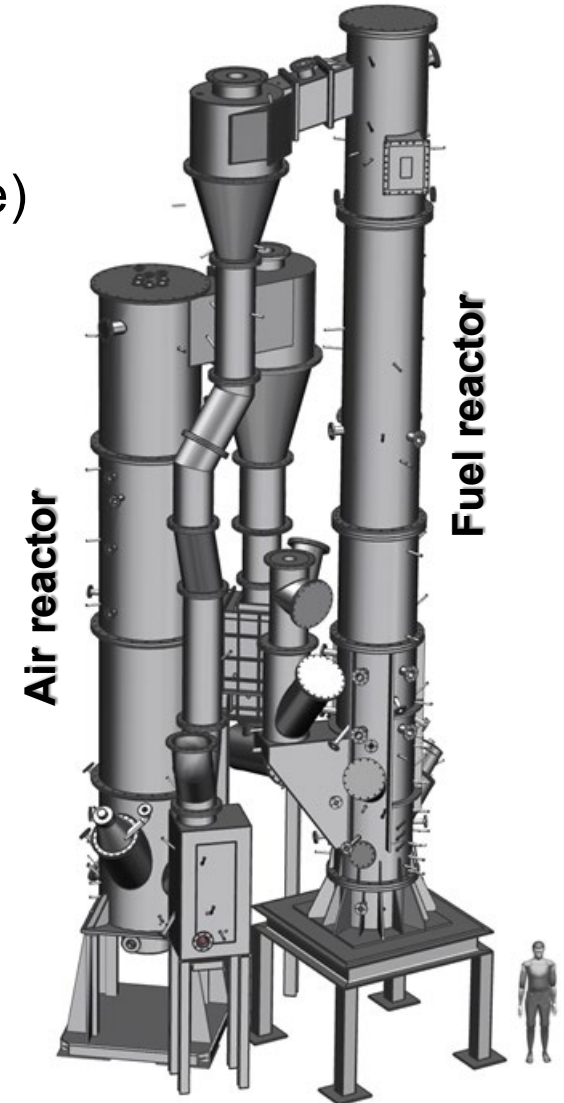
- measure off-gas SO_2 and NO (during T4.2)
 - AR, FR, POC
 - gas sample bags and FTIR measurements
 - determine SO_x and NO_x precursors
- calculate S and N balances
→ evaluate SO_x , NO_x and hydrocarbon emissions
- define measures for NO_x/SO_x emission control
 - air/oxygen staging, temperature control, and flue gas treatment (see WP3)



Conclusions & Outlook



- CLG of waste wood with **increased circulation** (done)
 - λ 0.4 – 0.7, T_{FR} 800 – 950 °C
 - 110 h autothermal operation
- CLC of forestry residues & SRF with **POC**
- **Corrosion** monitoring
- **Flexible** FBC/CLC operation
- FR with **packings**



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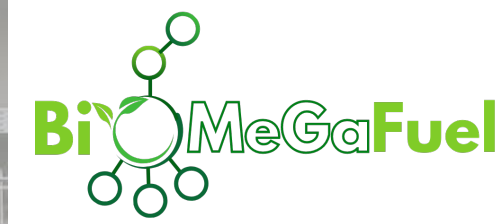
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Thank You



Chemical Looping (CL)

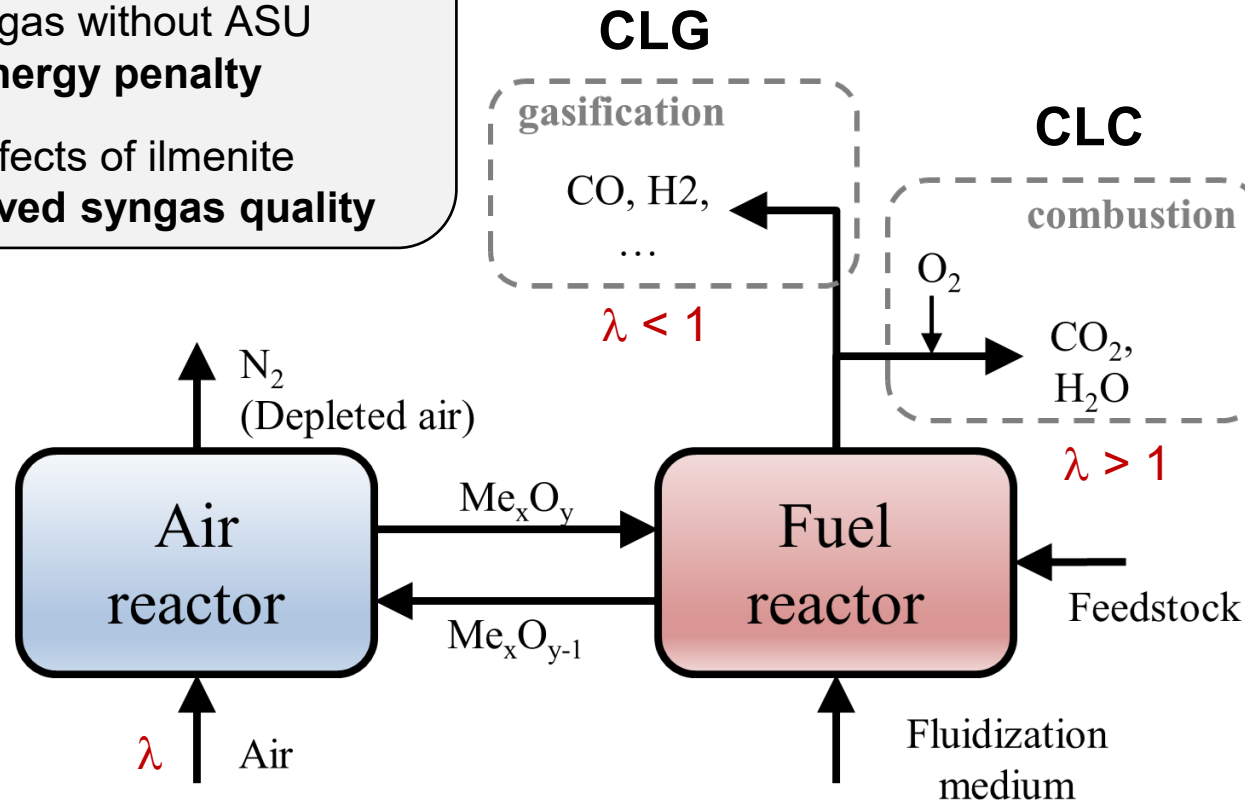
CLG benefits:

N_2 free syngas without ASU

→ **Low energy penalty**

Catalytic effects of ilmenite

→ **Improved syngas quality**



CLC benefits:

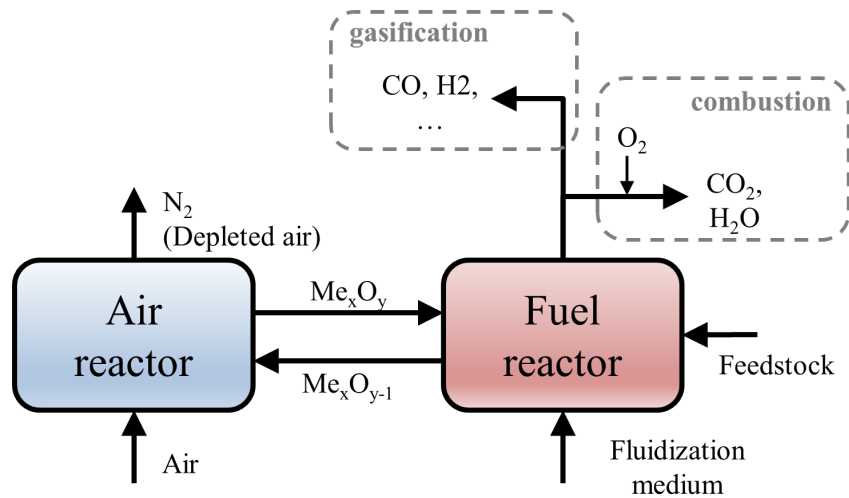
Inherent CO_2 separation

→ **Low energy penalty**

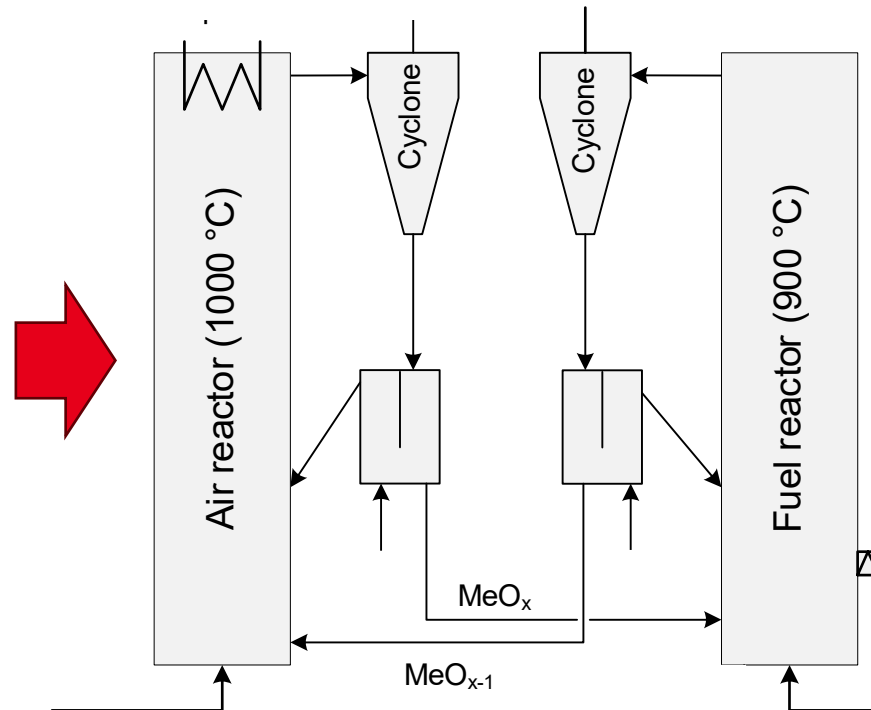
No problematic substances in air reactor

→ **High electrical efficiency**

CL Reactors



Dual fluidized bed system



1 MW_{th} dual
fluidized bed
pilot plant

