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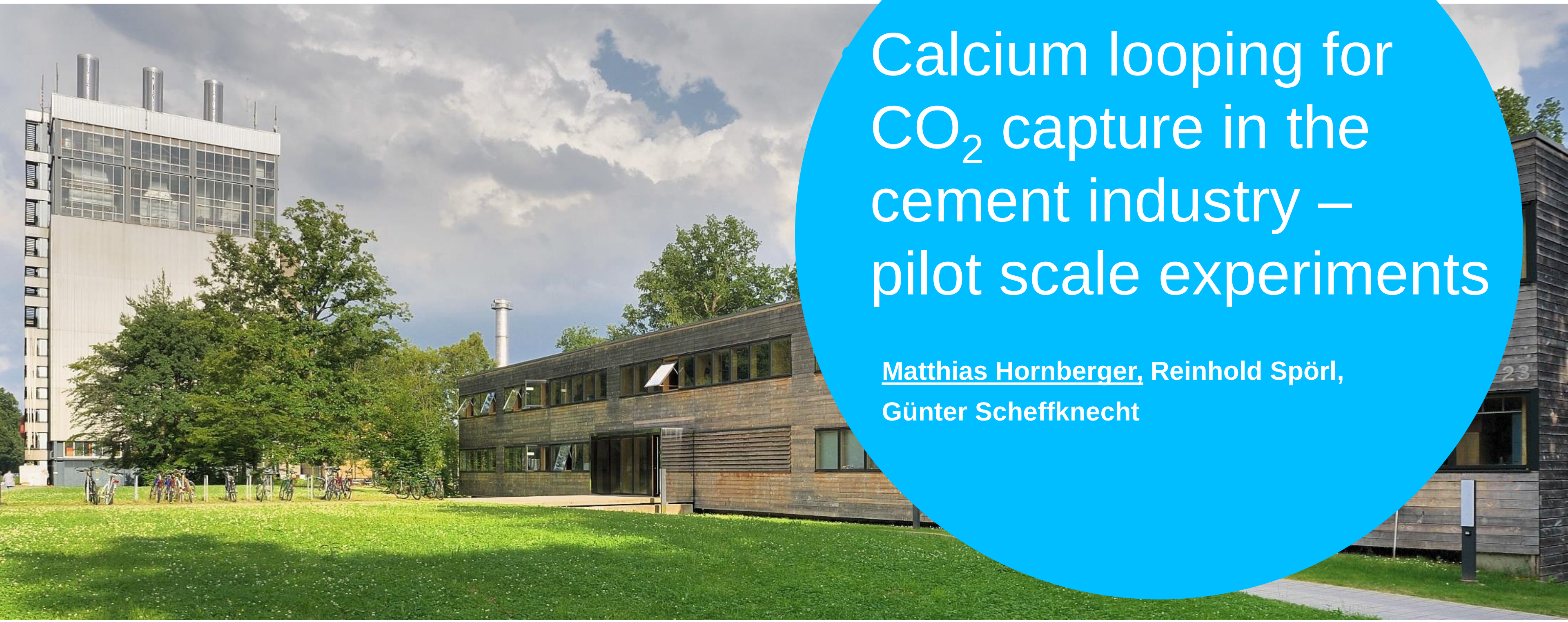

Calcium looping for CO_2 capture in the cement industry – pilot scale experiments

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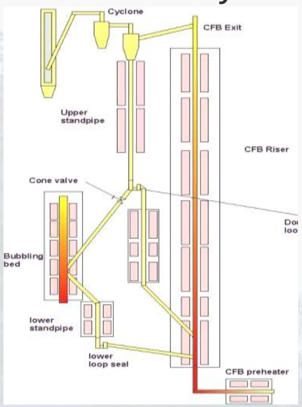
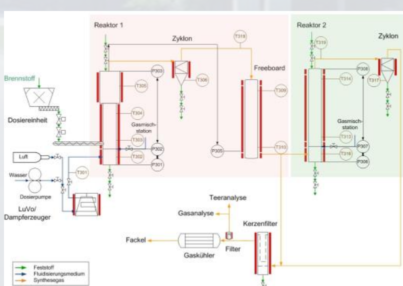
Expertise in Lime based Fluidized Bed Processes

20 kW_{th} electrically heated DFB System



5 kW_{th} electrically heated FB batch System



Fluidized Bed Processes

- ✓ Calcium Looping (CaL)
- ✓ Chemical Looping (CLC)
- ✓ Oxy-fuel CFB
- ✓ Sorption enhanced gasification (SEG)
- ✓ Oxy-fuel SER

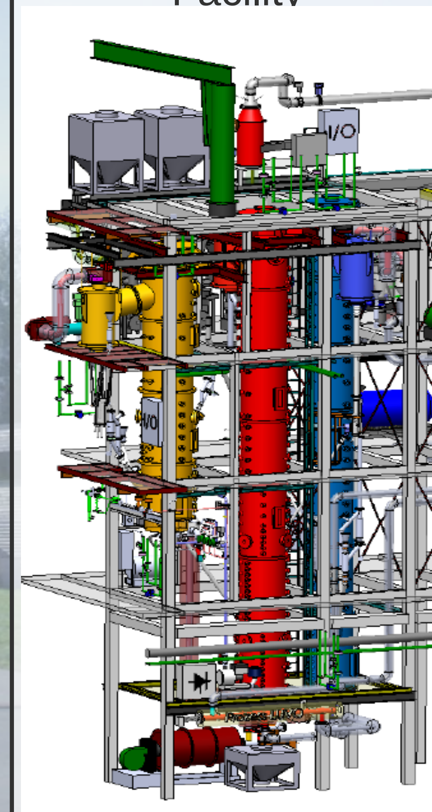
Fuels

- ✓ Biomass
- ✓ Waste
- ✓ Coal / Lignite

Measurement techniques

- ✓ Sorbent Characterization (TGA)
- ✓ Online gas analysis: CO_2, CO, O_2, H_2, CH_4, SO_x, NO_x
- ✓ Non-condensable HC: GC
- ✓ Tar: wet chemical & online (FID)
- ✓ H_2S, HCl, NH_3: wet chemical

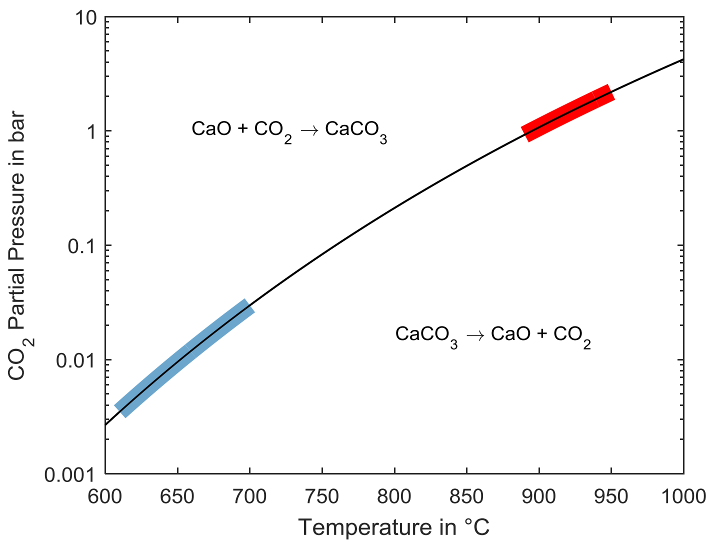
200 kW_{th} DFB Pilot Facility

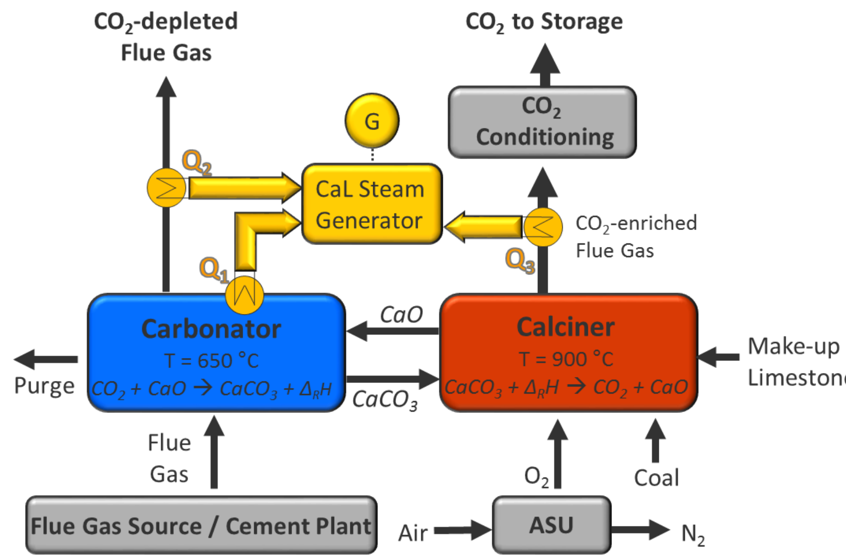


Calcium – Looping

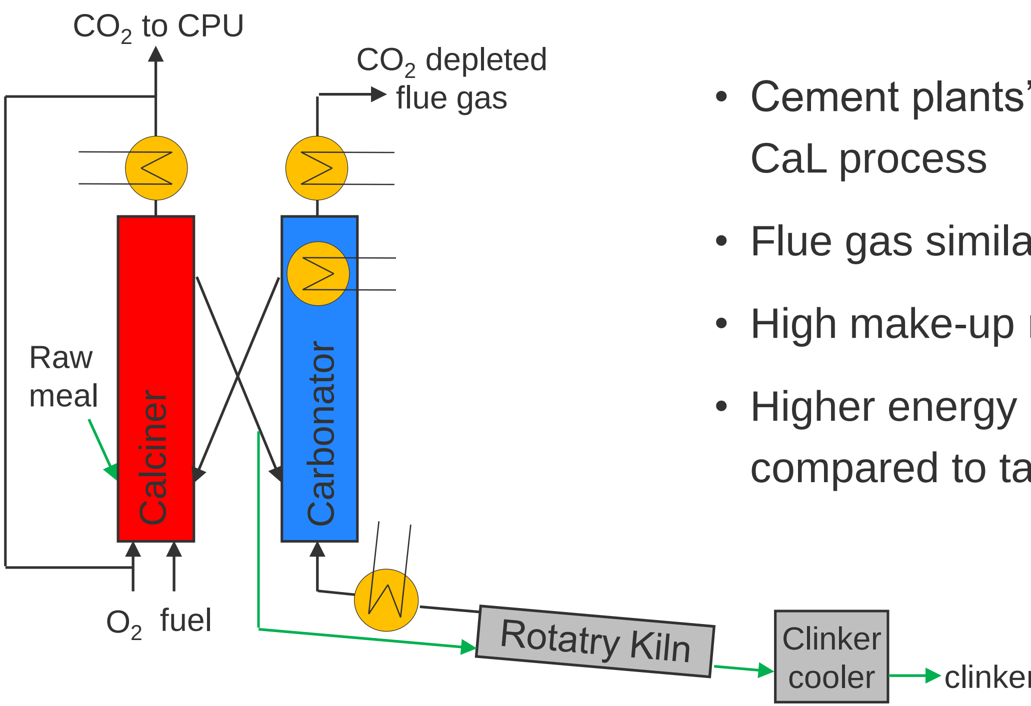
Calcium Looping – Basics

- CO_2 capture by cyclic calcination and carbonation of Calciumcarbonat ($CaCO_3$)
- High energy efficiency due to high temperature level



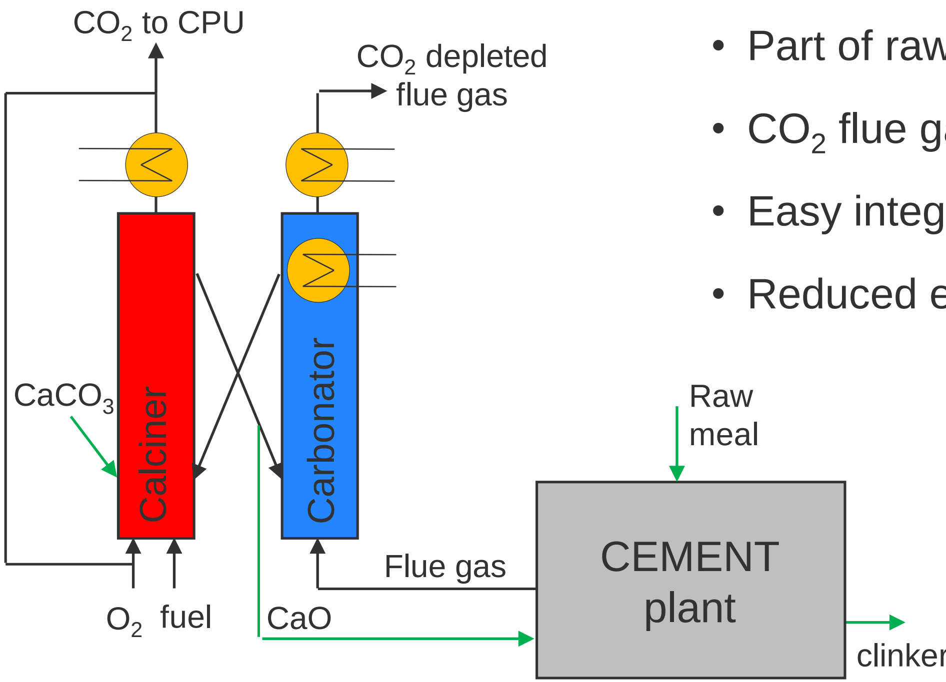


Calcium Looping – Cement Plant Integration



- Cement plants' raw meal completely calcined by CaL process
- Flue gas similar to power plant application
- High make-up ratio realizable
- Higher energy efficiency and higher complexity compared to tail-end

Calcium Looping – Cement Plant Integration



- Part of raw meal calcined in CaL process
- CO_2 flue gas concentration ~ 20 - 35 %
- Easy integration
- Reduced energy efficiency

Experimental facility –
200 kW_{th} pilot plant (MAGNUS)

Fluidized Bed Research Facilities – MAGNUS

200 – 230 kW$_{th}$ pilot scale facility (3 reactors)

Bubbling bed reactor (1x)

- diameter: 330 mm
- height: 6 m

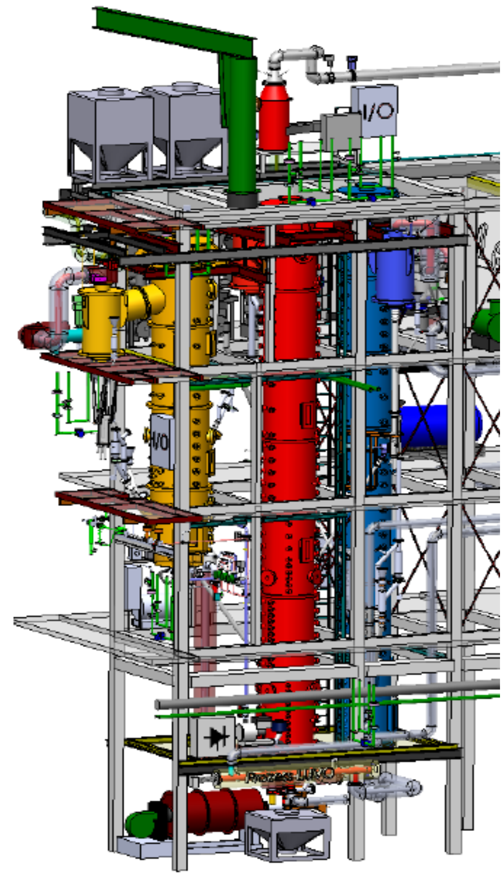
Circulating fluidized bed reactor (2x)

- diameter: 200 mm
- height: 10 m

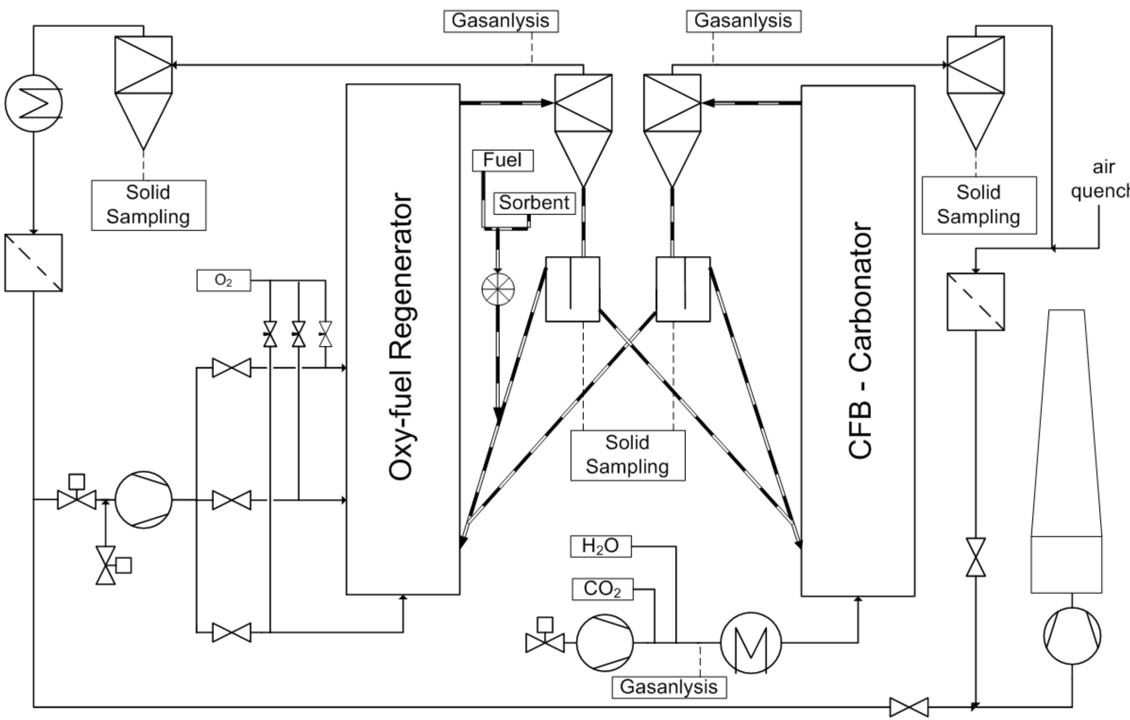
Possible reactor configuration: CFB-CFB, BFB-CFB

No electrical heating (heated by combustion)

Gas analysis (H_2, CO, CH_4, O_2, CO_2, C_xH_y, SO_2, NO_X)



MAGNUS – CFB-CFB configuration



- CFB reactors coupled by cone valves installed in loop seals
- Synthetic flue gas mixed by air, CO_2 and steam
- Hot flue recirculation in case of oxy-fuel operation
- Solid transfer measured by microwave sensors

MAGNUS – BFB-CFB configuration

- Coupling by conveyer screw in loop seal stand pipe and bottom loop seal
- Solid transfer proportional to rotation speed
- Various sampling ports for gas analysis and solid sampling
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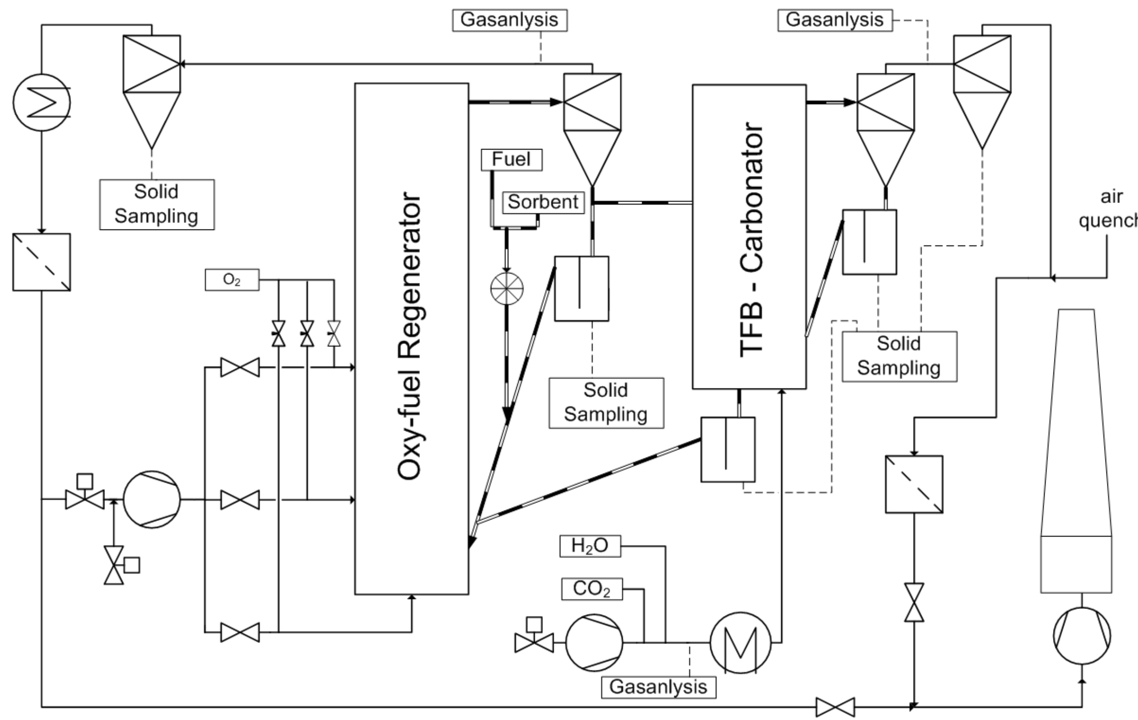


Experimental conditions

Carbonator (CFB, TFB):

- Flue gas:
  - y_{H2O} ~ 15 %
  - $y_{CO2,dry}$ ~ 15 %*

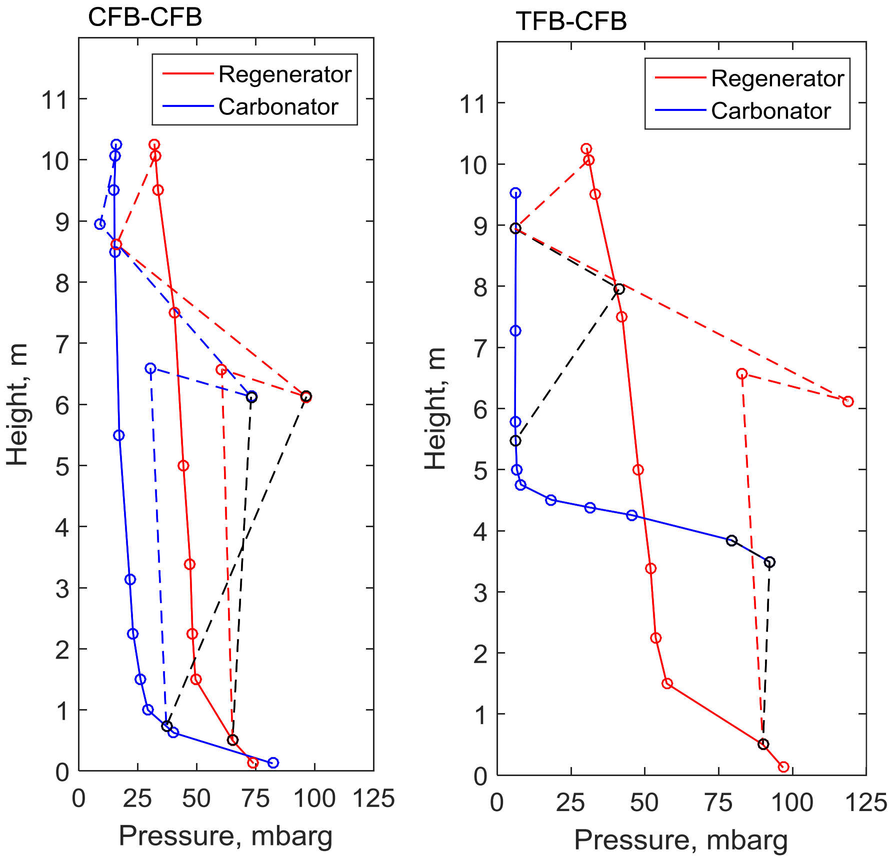
Gas analysis:

- Confirmation of calibration every 24 h
- NDIR online gas analyzers
- Periodic cleaning of gas filters

Calciner / Regenerator (CFB):

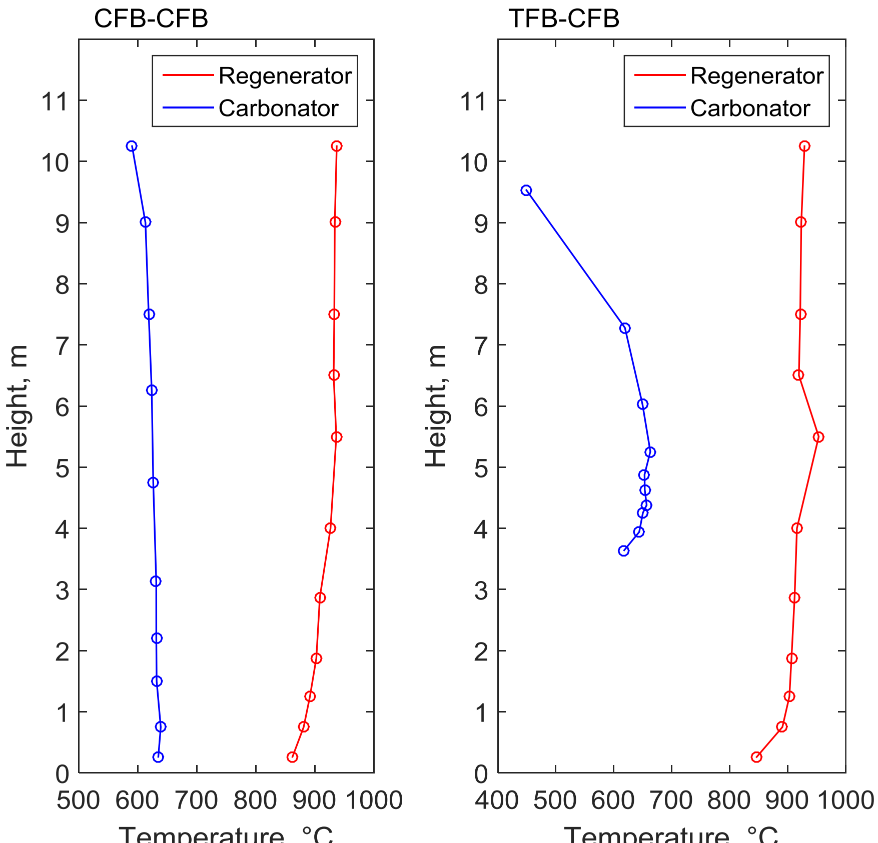
- Oxy-fuel: hot recirculated flue gas from calciner mixed with O_2
- Staged oxidant feeding
- Fuel: Columbian hard coal
- Sorbent: Limestone from western Germany

Experimental results – Hydrodynamic



- Hydrodynamic is essential for stable operation
- Internal recirculation enables self-stabilizing of CFB reactors
- Bed inventory is adjustable by pressure difference between the reactors
- homogeneous solid distribution in CFB risers
- Dense region at bottom of TFB carbonator

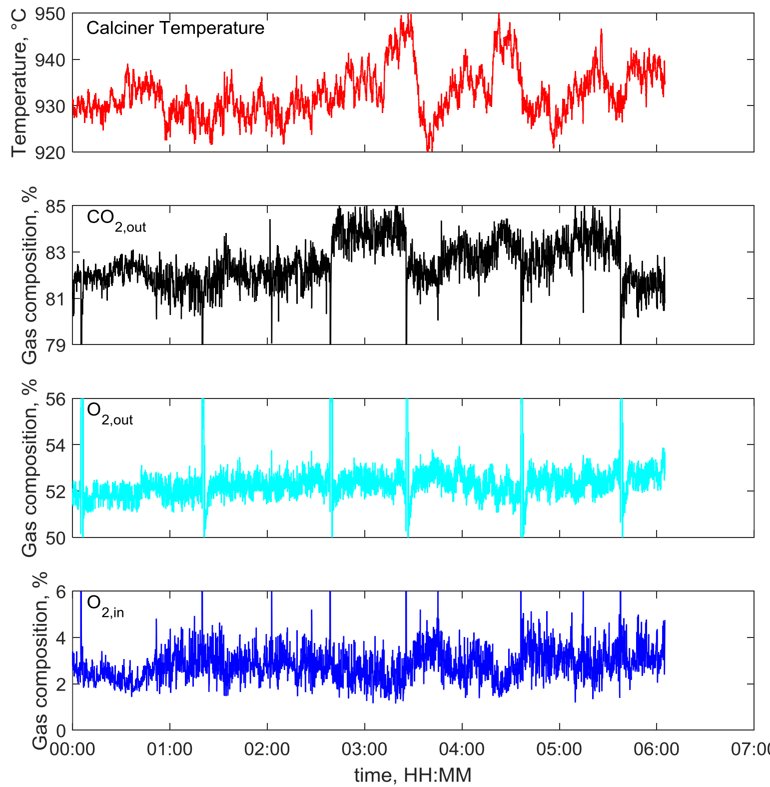
Experimental results – Temperature profile



- Calcination reaction of limestone moderates calciner temperature
- Uniform reaction conditions beneficial for
  - sorbent properties
  - combustion performance

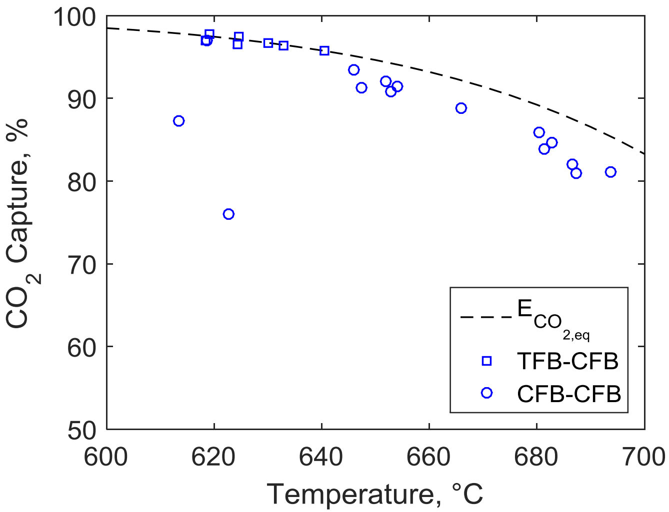
Experimental results – Calciner operation

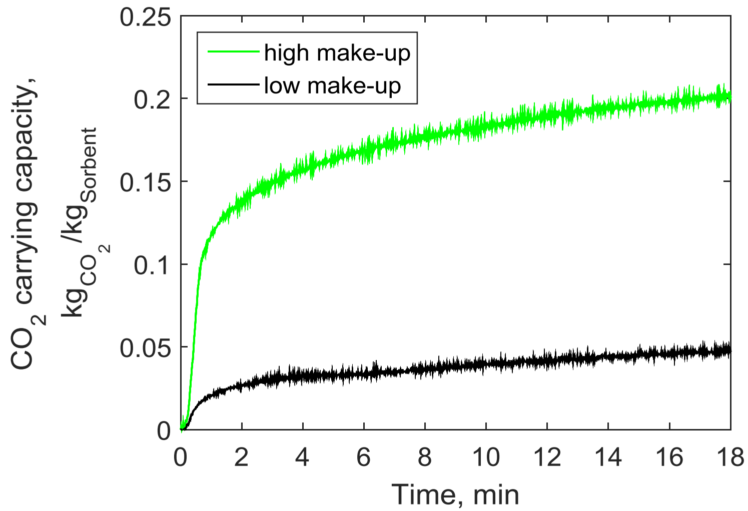
- Increase in thermal duty with make-up due to endothermic calcination reaction
- High O_2 demand required to obtain a consistent velocity
- Low recirculation of calciner off gas (< 30 %)



Experimental results – CO_2 capture

- CO_2 capture was limited by the equilibrium CO_2 capture
- High CO_2 capture rate above 90 % reached
- High sorbent activity due to high make-up flows





Summary, Outlook, Conclusion

Conclusion and Outlook

- Beneficial Calcium Looping operation conditions due to reutilization of sorbent in cement plant
- >90 % CO_2 capture in carbonator achieve over a wide range of parameters
- High make-up rates cause an increased thermal load of the calciner and require higher calciner oxygen concentrations

- Calcium Looping highly promising for CO_2 capture from cement manufacturing
- Experiments on tail-end Calcium Looping CO_2 capture form cement manufacturing ongoing

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Thank you!

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