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Calcium Looping Post Combustion CO_2 Capture: A promising technology for emission free cement production

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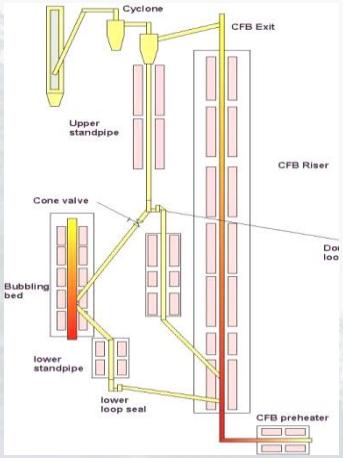
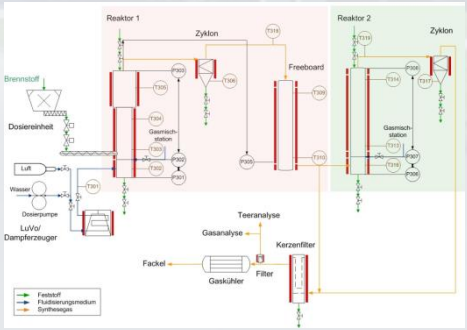
The 6th High Temperature Solid Looping Cycles Network Meeting,
September 1st, 2015, Milan

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 reforming (SER)
- ✓ Oxy-fuel SER

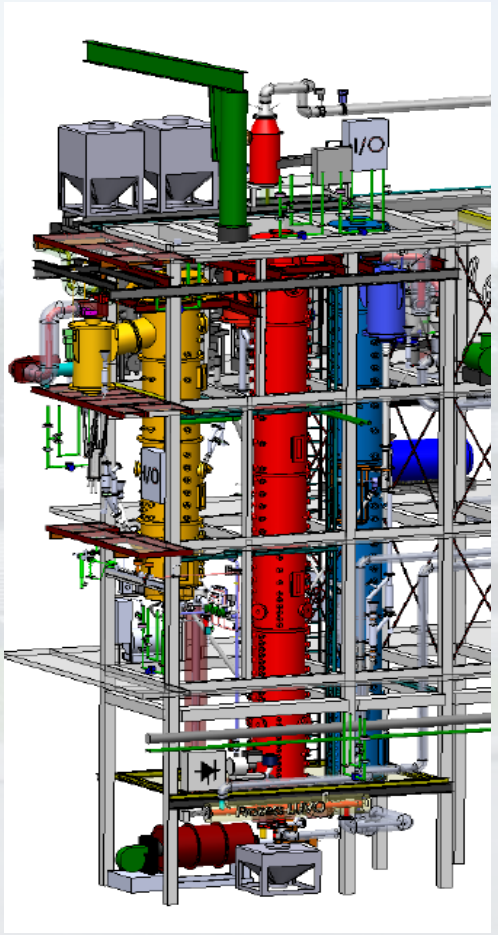
Fuels

- ✓ Biomass
- ✓ Waste
- ✓ Lignite / Coal

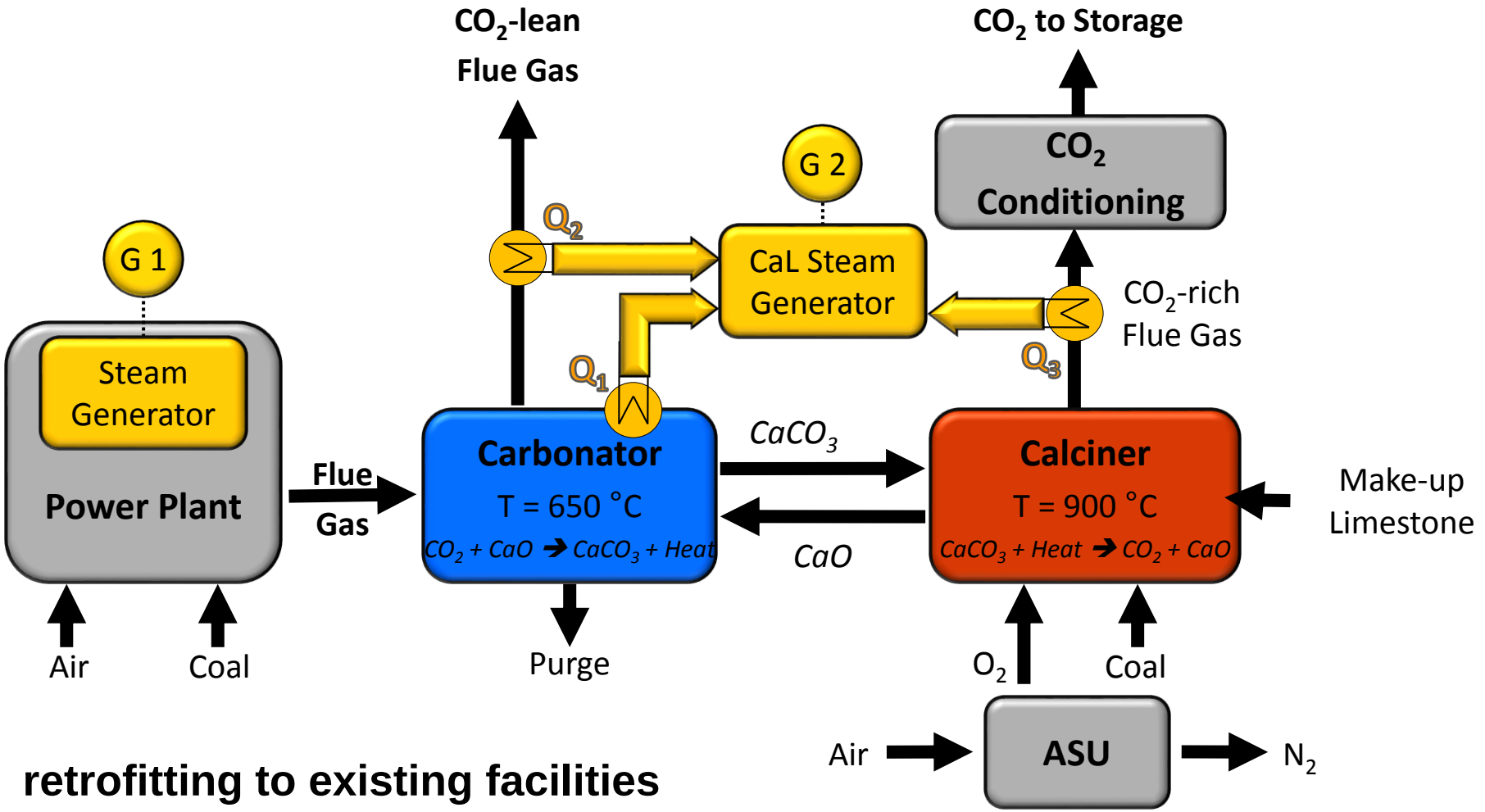
Measurement techniques

- ✓ 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 – Post Combustion CCS



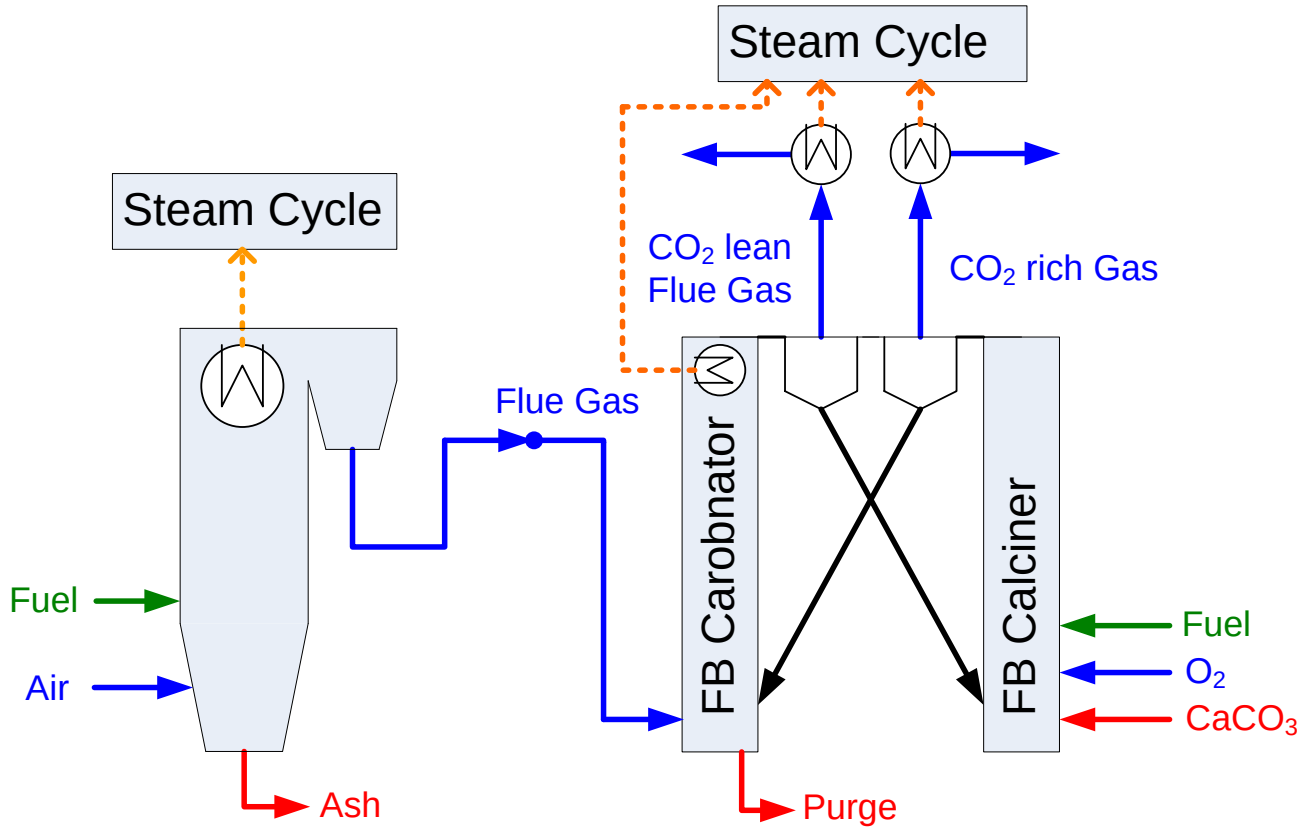
- **retrofitting to existing facilities**
- **low CO_2 separation cost**
- **low efficiency penalty**

Calcium Looping – Post Combustion CCS

General conditions

- Looping Ratio: 2 - 10
- Make-up Ratio: < 0,1 - 0,4
- Temperature
  - $T_{Calciner}$: 850 - 1000 °C
  - $T_{Carbonator}$: 600 - 700 °C
- Flue gas
  - CO_2: ~ 15 %

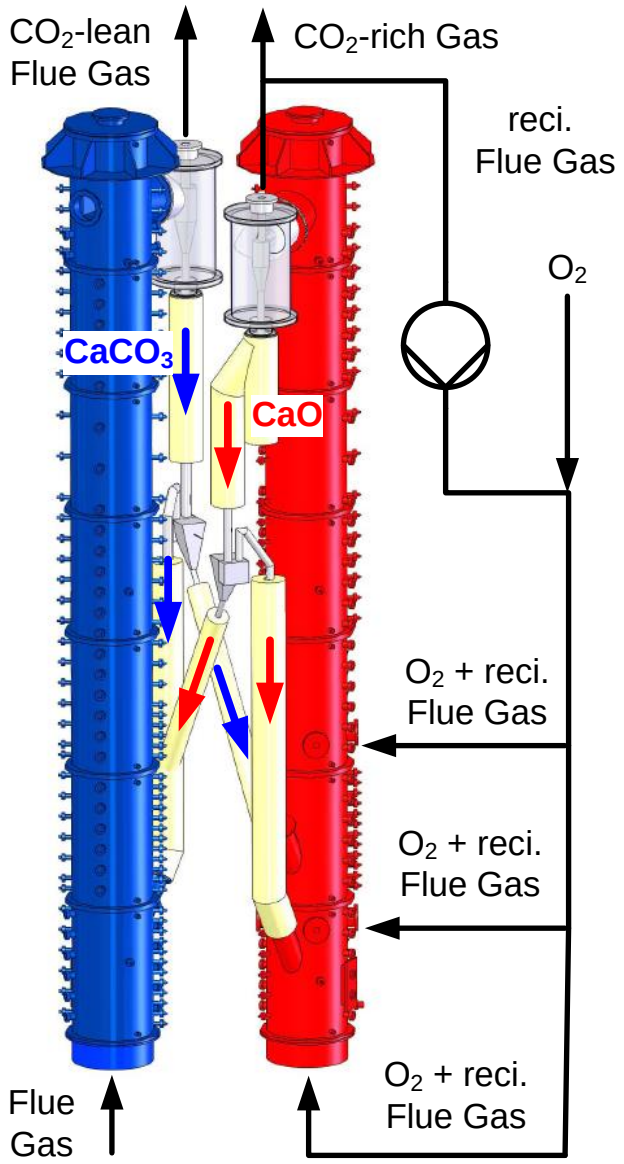
$$CaO + CO_2 \underset{\text{Calcination}}{\overset{\text{Carbonation}}{\rightleftharpoons}} CaCO_3 + \text{Heat}$$



Calcium Looping – Pilot Plant (200 kW_{th})

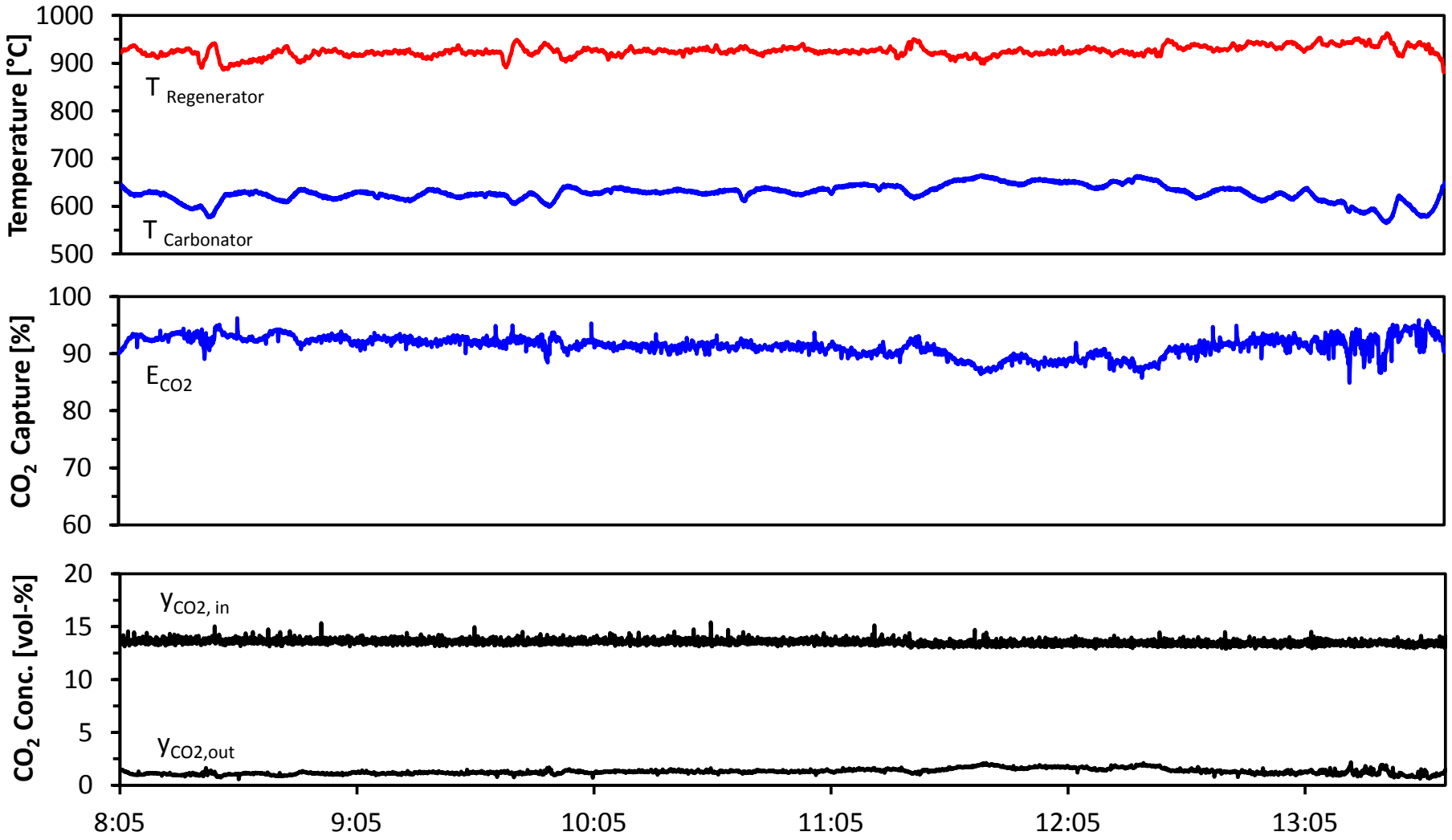
Operation Conditions

- Flue Gas Load: 170 - 230 kW_{th}
- Sorbent Looping Ratio: 3 - 13 mol_{CaO}/mol_{CO_2}
- Total Solid Inventory: 70 - 120 kg $CaO/CaCO_3$

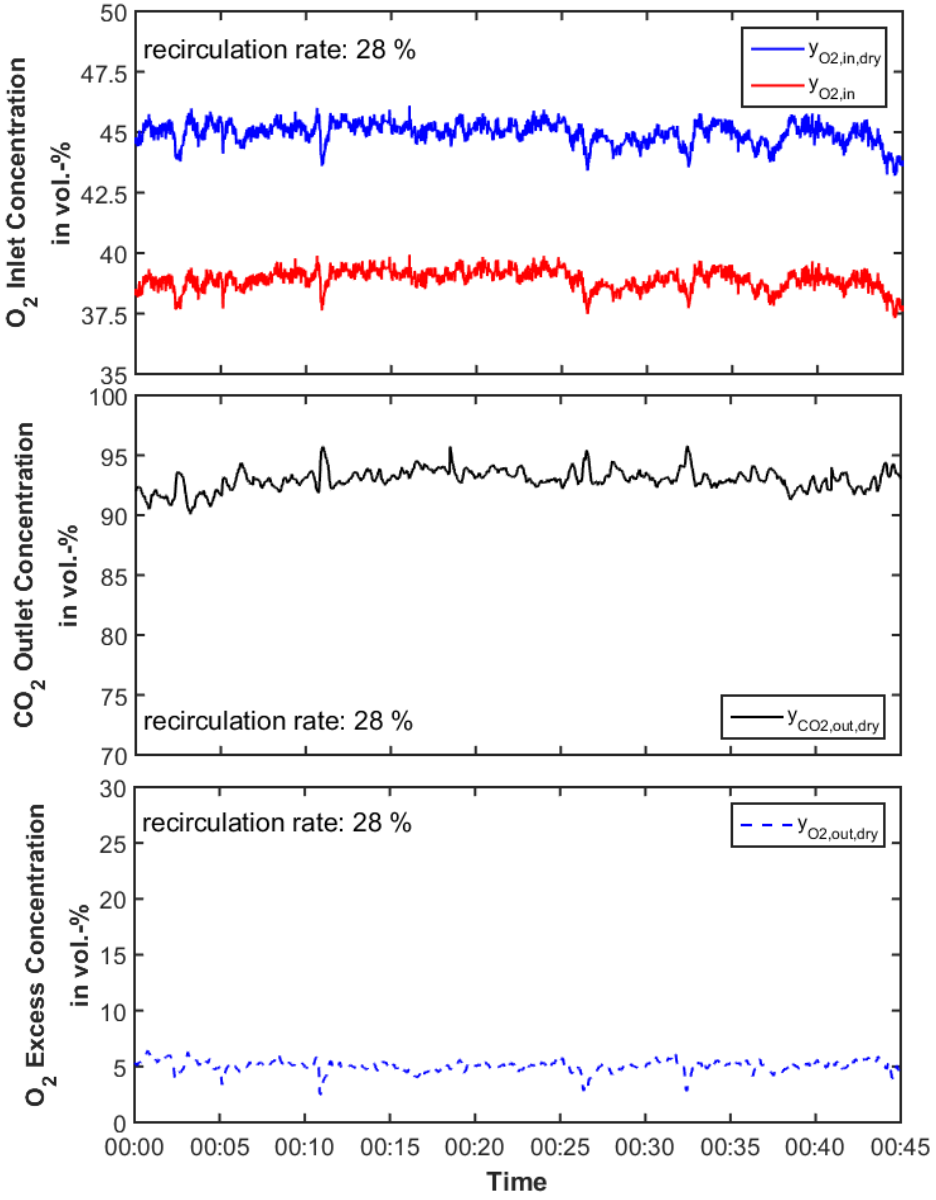


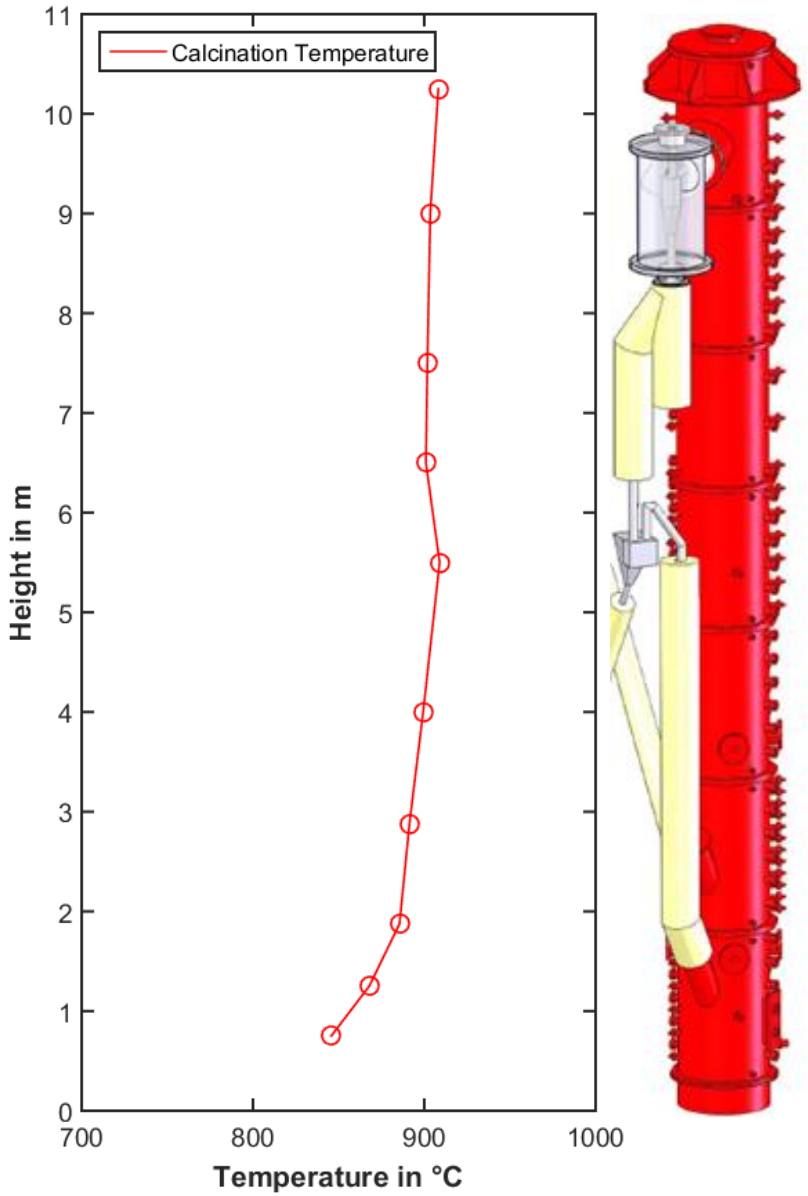
Operational Results – Carbonator

- **Over 90% capture efficiency** achieved over a wide range of operating conditions



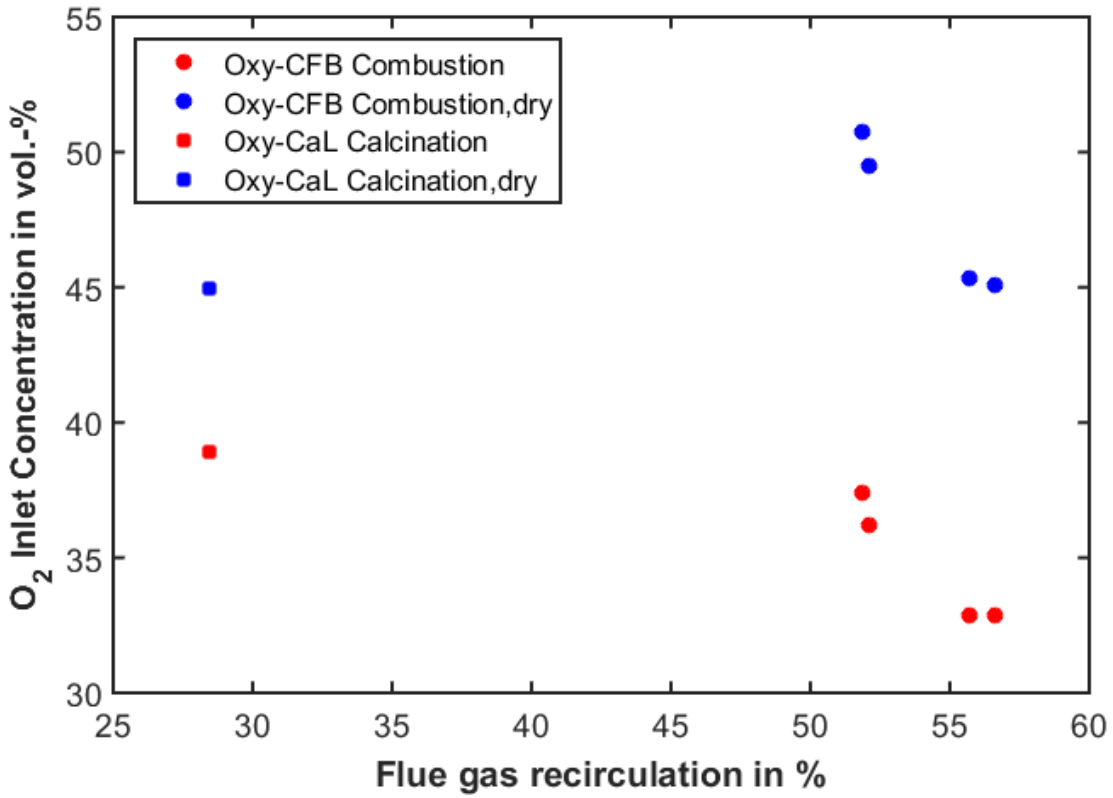
Operational Results – Oxy-fuel Calcination





Operational Results – Oxy-fuel Calcination

- High inlet oxygen concentrations (> 50 vol.-%,dry) possible
- lower recirculation rates for oxy-CaL calcination (additional CO_2 from calcination)
- lower humidity of CaL flue gas
- uniform isothermal conditions



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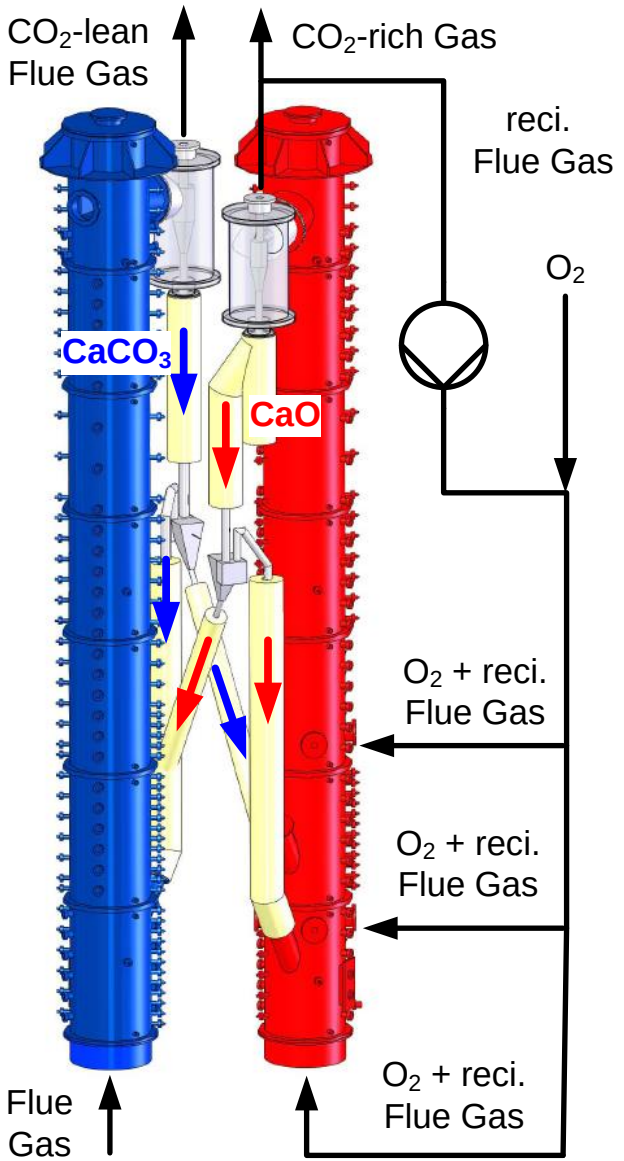
Carbonator

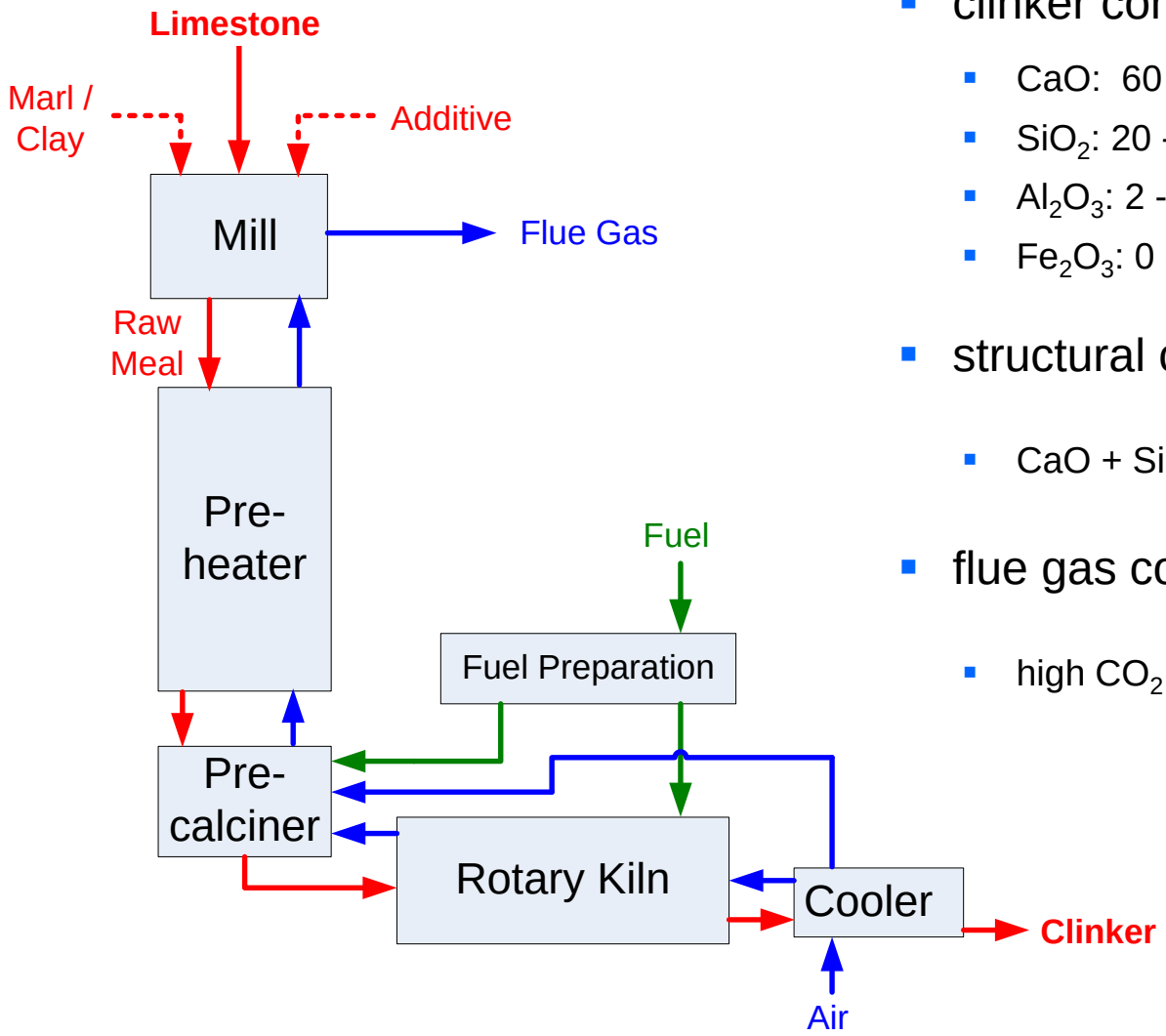
- CO_2 capture efficiency above 90 %

Calciner

- CO_2 outlet concentrations above 90 vol.-%,dry
- Inlet O_2 concentrations above 50 vol.-%,dry
- Excess O_2 outlet concentration below 3 vol.-% ,dry



Cement Plant – Clinker Production and Properties



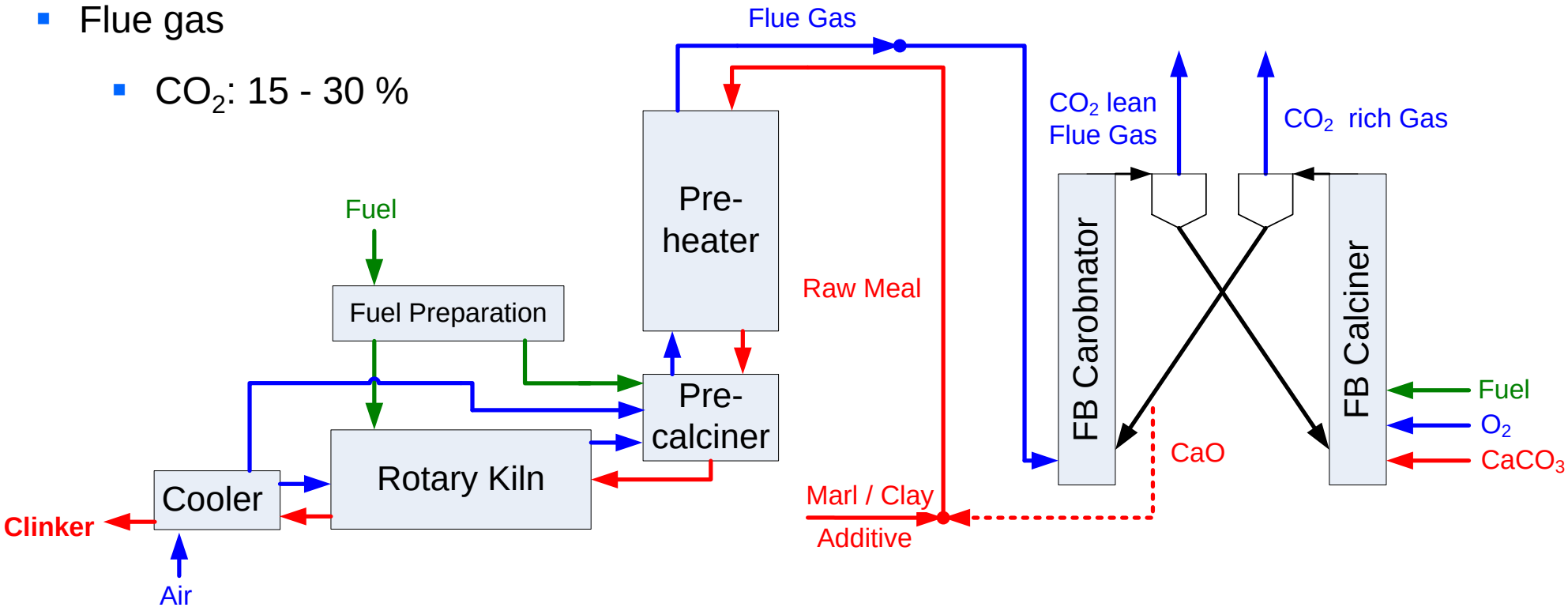
- clinker composition
  - CaO: 60 - 70 %
  - SiO_2: 20 - 25 %
  - Al_2O_3: 2 - 6 %
  - Fe_2O_3: 0 - 6 %
- structural change at 1400 °C (rotary kiln)
  - $CaO + SiO_2 \rightarrow (CaO)_3 \cdot SiO_2$ & $(CaO)_2 \cdot SiO_2$
- flue gas composition
  - high CO_2 concentration ~ 30 %

Cement Plant – CaL Integration

- **synergy effect between cement plant and CaL-process**

General conditions

- Looping Ratio: 2 - 4
- Make-up Ratio: > 1
- Flue gas
  - CO_2: 15 - 30 %



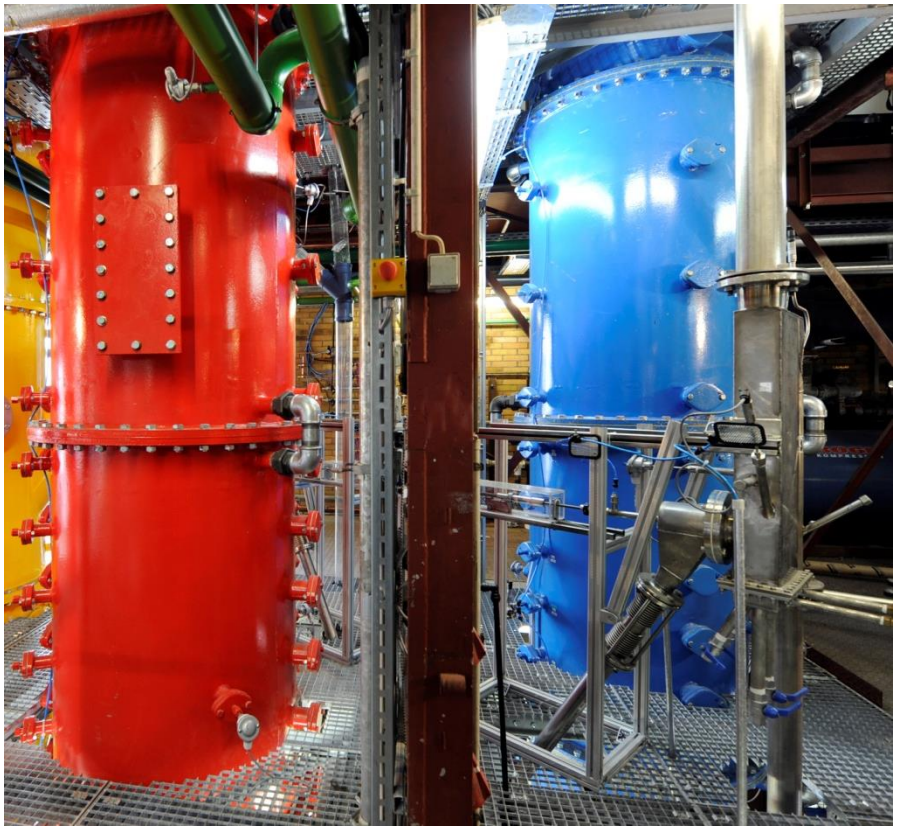
Summary

- **Calcium looping for power plant application demonstrated at pilot plant scale**
  - CO_2 capture efficiency over 90 %
  - CO_2 concentrations over 90 %

- **Feasibility for cement plant application will be investigated at pilot plant scale**
  - Effect of high CO_2 flue gas concentration
  - Influence of make-up ratio, sorbent looping ratio
  - Optimal operation conditions

Thank you for your interest!

Any Questions?



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