



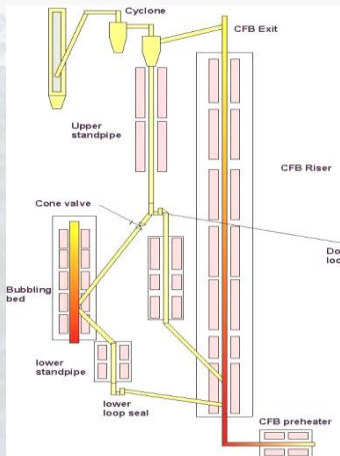
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# Calcium Looping Post Combustion CO<sub>2</sub> Capture: A promising technology for emission free cement production

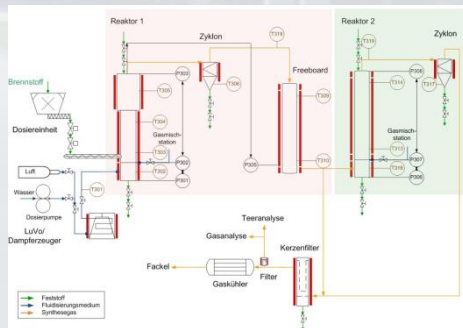
**M. Hornberger, H. Dieter, G. Scheffknecht**

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

20 kW<sub>th</sub> electrically heated DFB System



5 kW<sub>th</sub> electrically heated FB batch System



## Fluidized Bed Processes

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

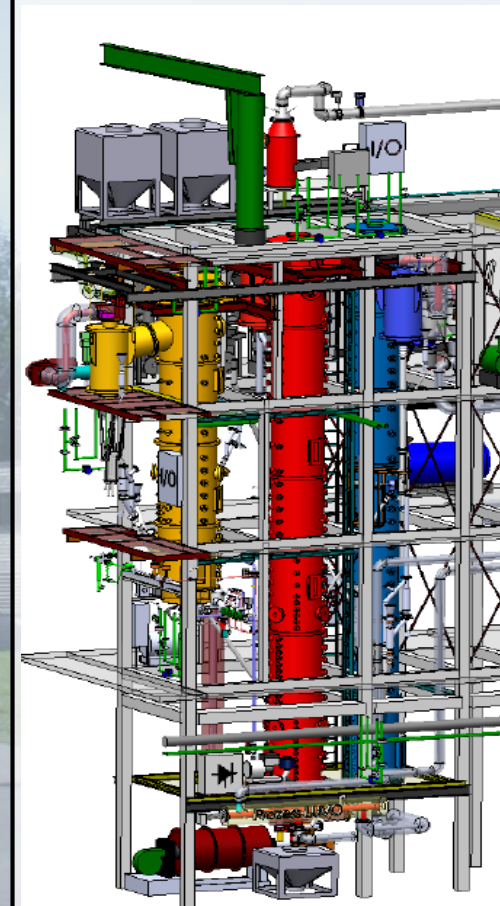
## Fuels

- ✓ Biomass
- ✓ Waste
- ✓ Lignite / Coal

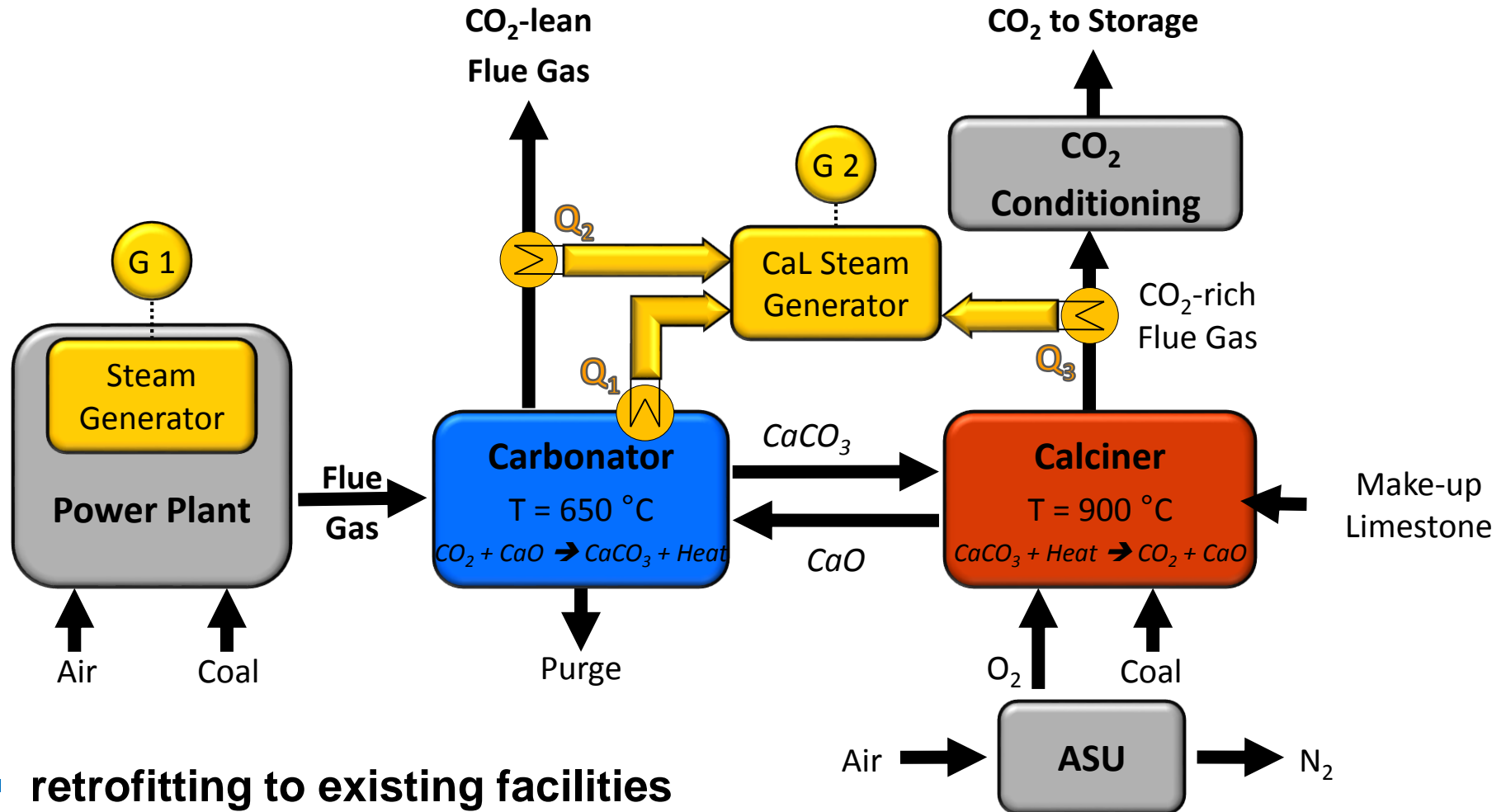
## Measurement techniques

- ✓ Sorbent Characterization (TGA)
- ✓ Online gas analysis:  
CO<sub>2</sub>, CO, O<sub>2</sub>, H<sub>2</sub>, CH<sub>4</sub>, SO<sub>x</sub>, NO<sub>x</sub>
- ✓ Non-condensable HC: GC
- ✓ Tar: wet chemical & online (FID)
- ✓ H<sub>2</sub>S, HCl, NH<sub>3</sub>: wet chemical

200 kW<sub>th</sub> DFB Pilot Facility



# Calcium Looping – Post Combustion CCS

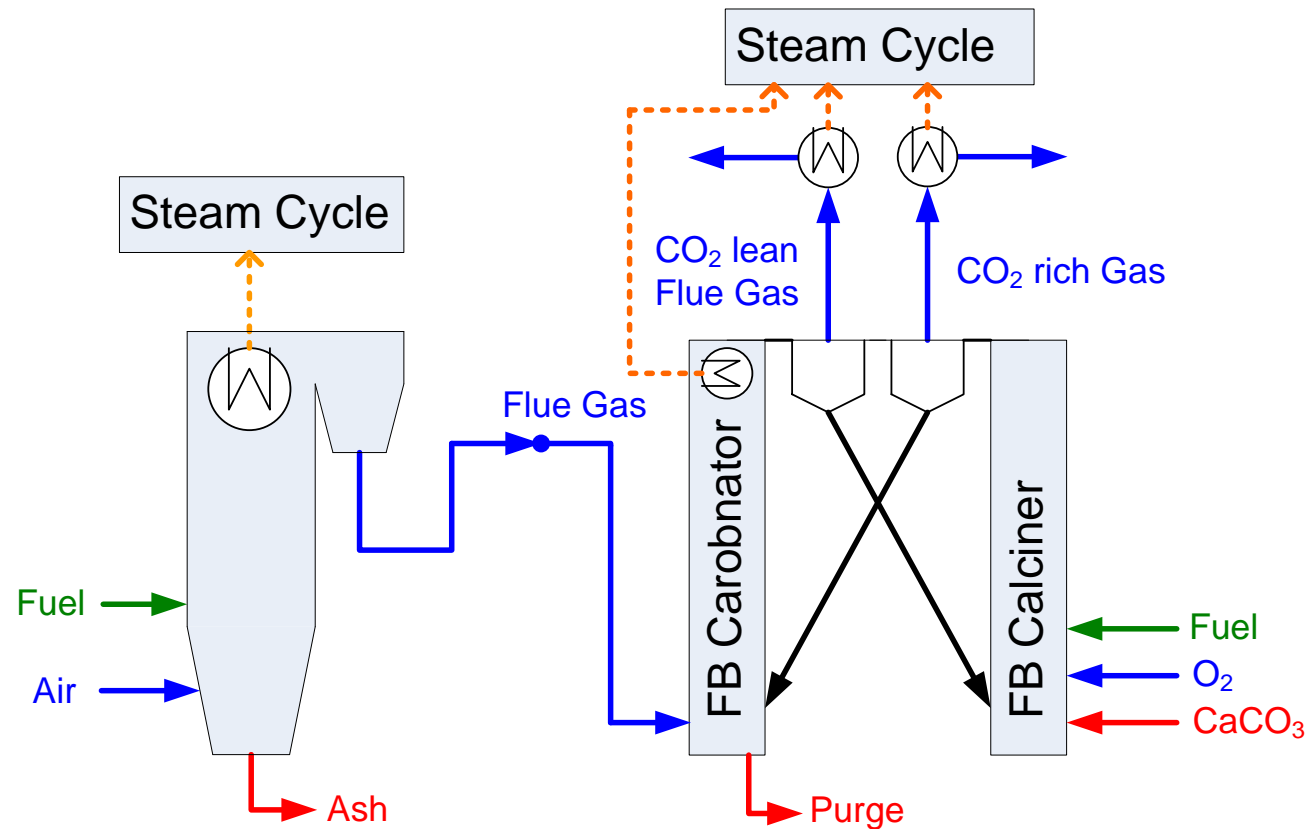
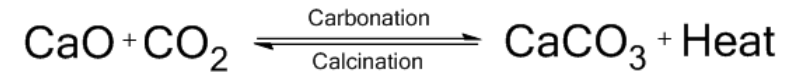


- retrofitting to existing facilities
- low CO<sub>2</sub> separation cost
- low efficiency penalty

# Calcium Looping – Post Combustion CCS

## General conditions

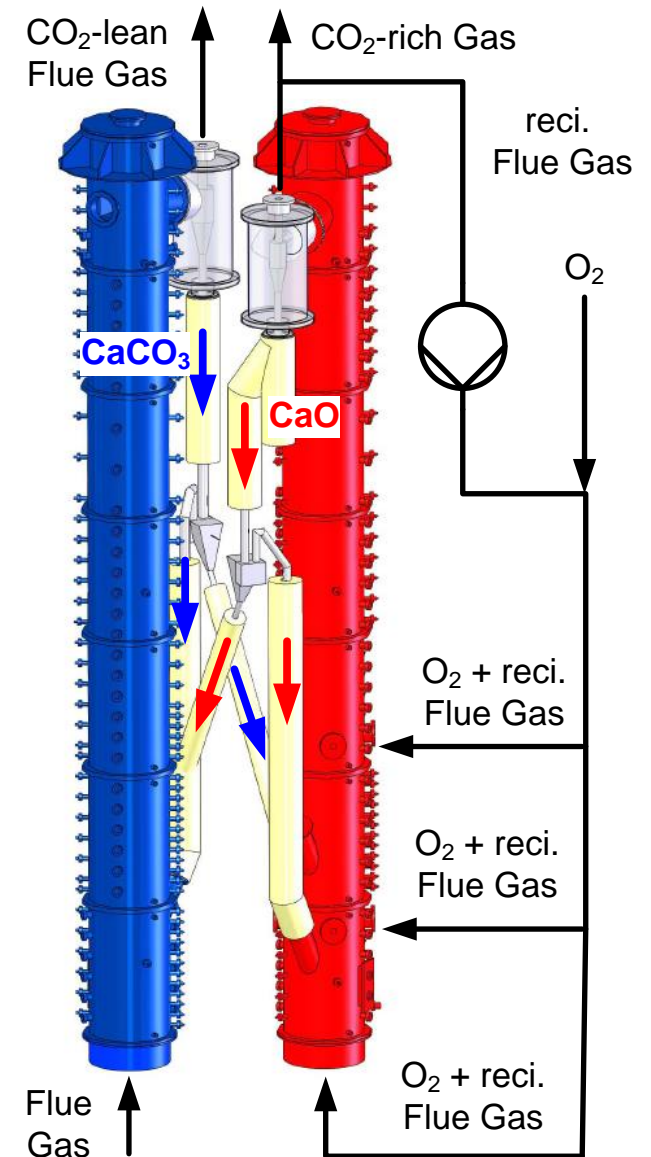
- Looping Ratio: 2 - 10
- Make-up Ratio: < 0,1 - 0,4
- Temperature
  - $T_{\text{Calciner}}$ : 850 - 1000 °C
  - $T_{\text{Carbonator}}$ : 600 - 700 °C
- Flue gas
  - $\text{CO}_2$ : ~ 15 %



# Calcium Looping – Pilot Plant (200 kW<sub>th</sub>)

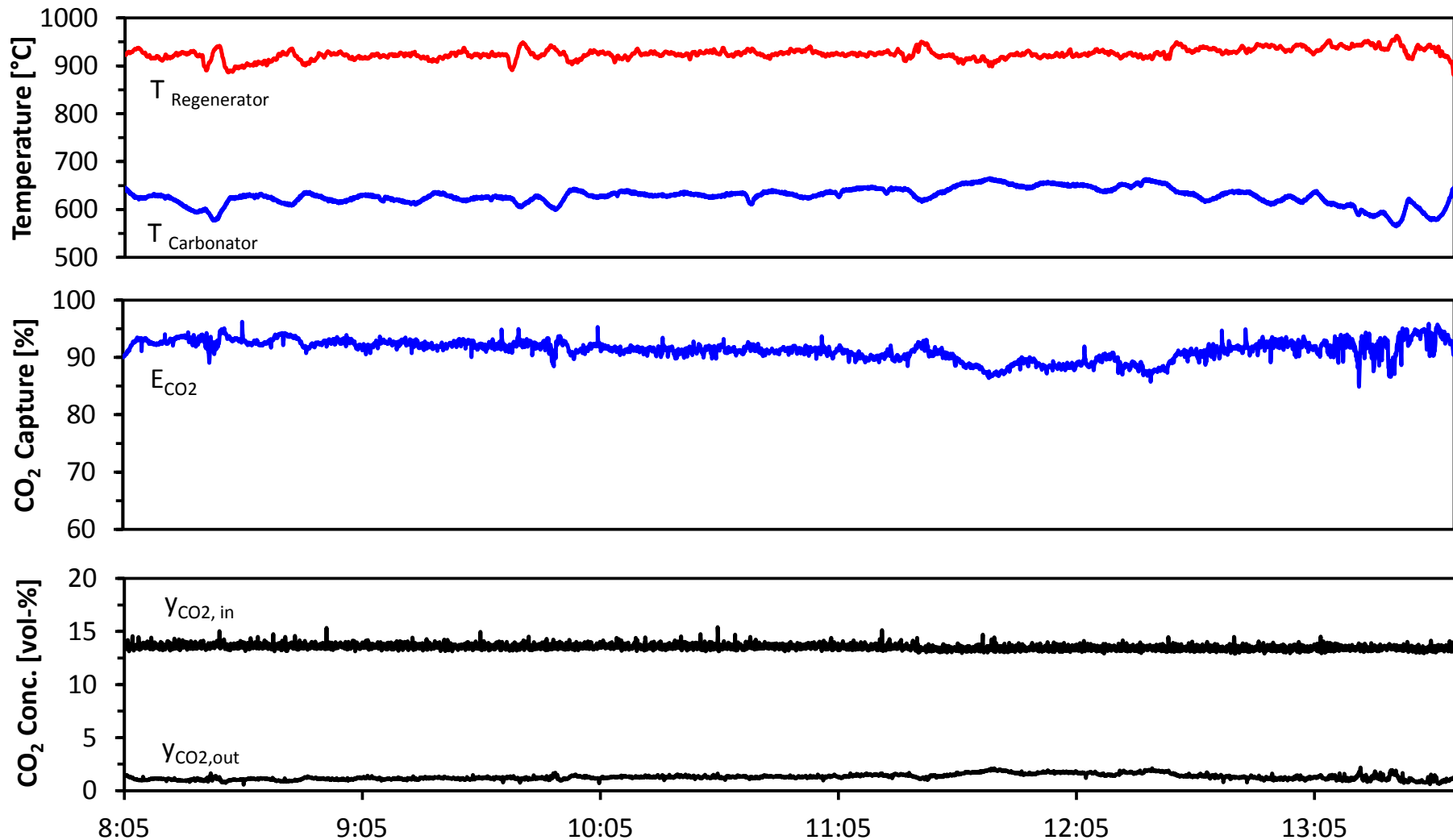
## Operation Conditions

- Flue Gas Load: 170 - 230 kW<sub>th</sub>
- Sorbent Looping Ratio: 3 - 13 mol<sub>CaO</sub>/mol<sub>CO<sub>2</sub></sub>
- Total Solid Inventory: 70 - 120 kg CaO/CaCO<sub>3</sub>

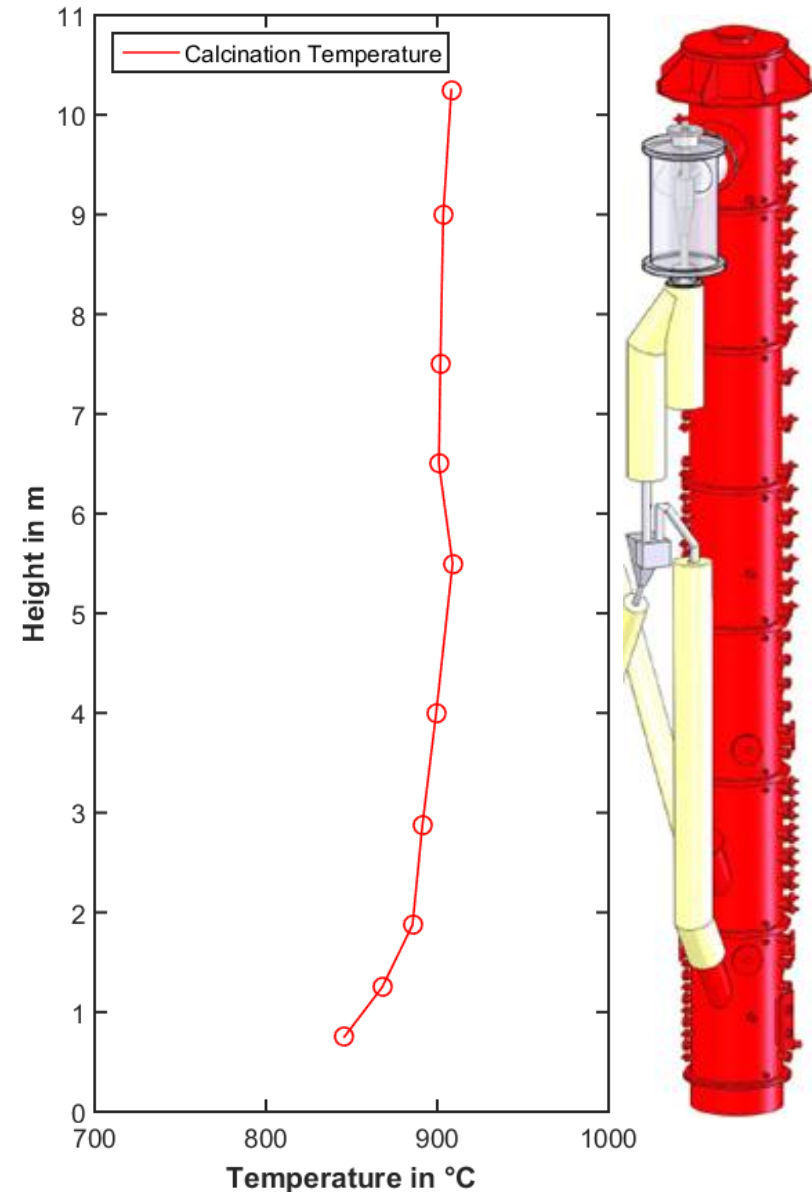
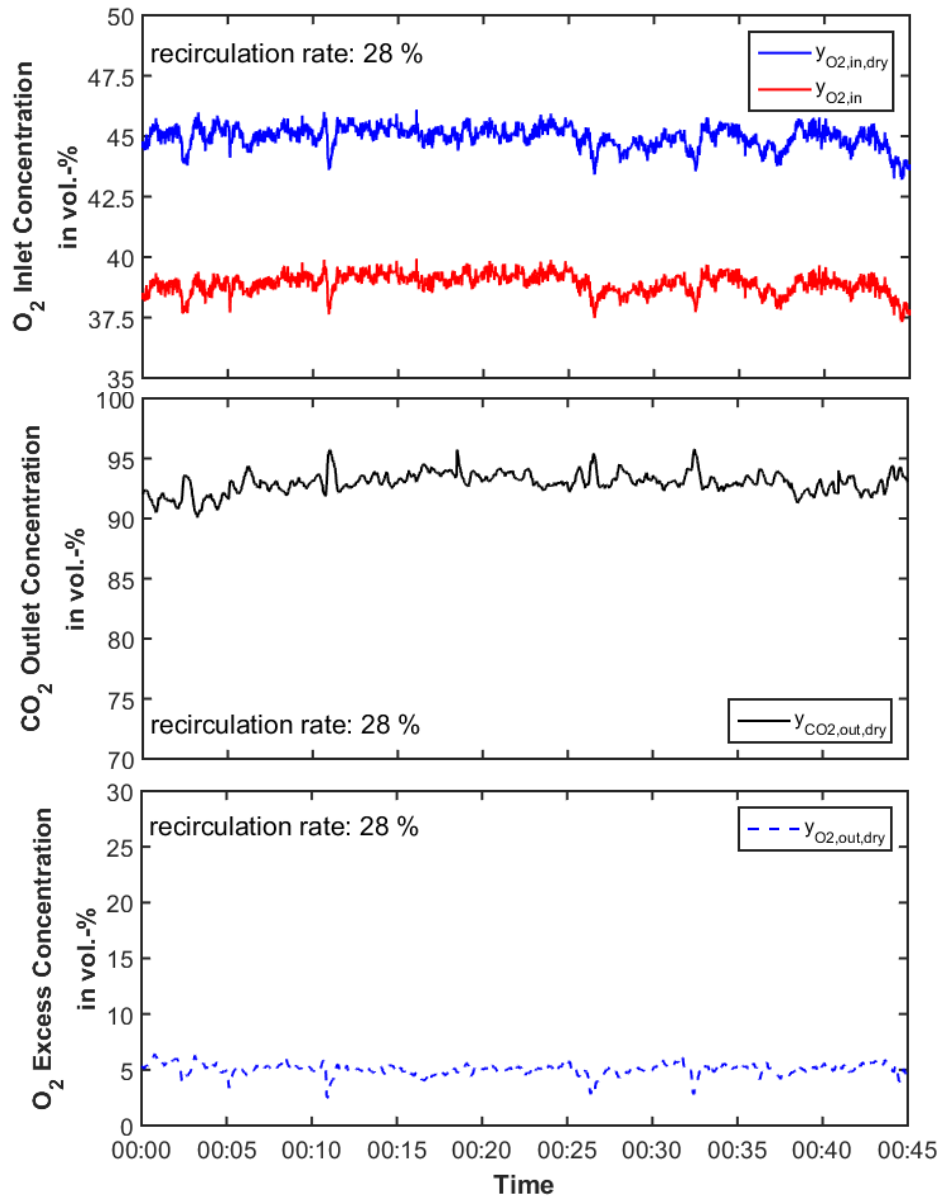


# Operational Results – Carbonator

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

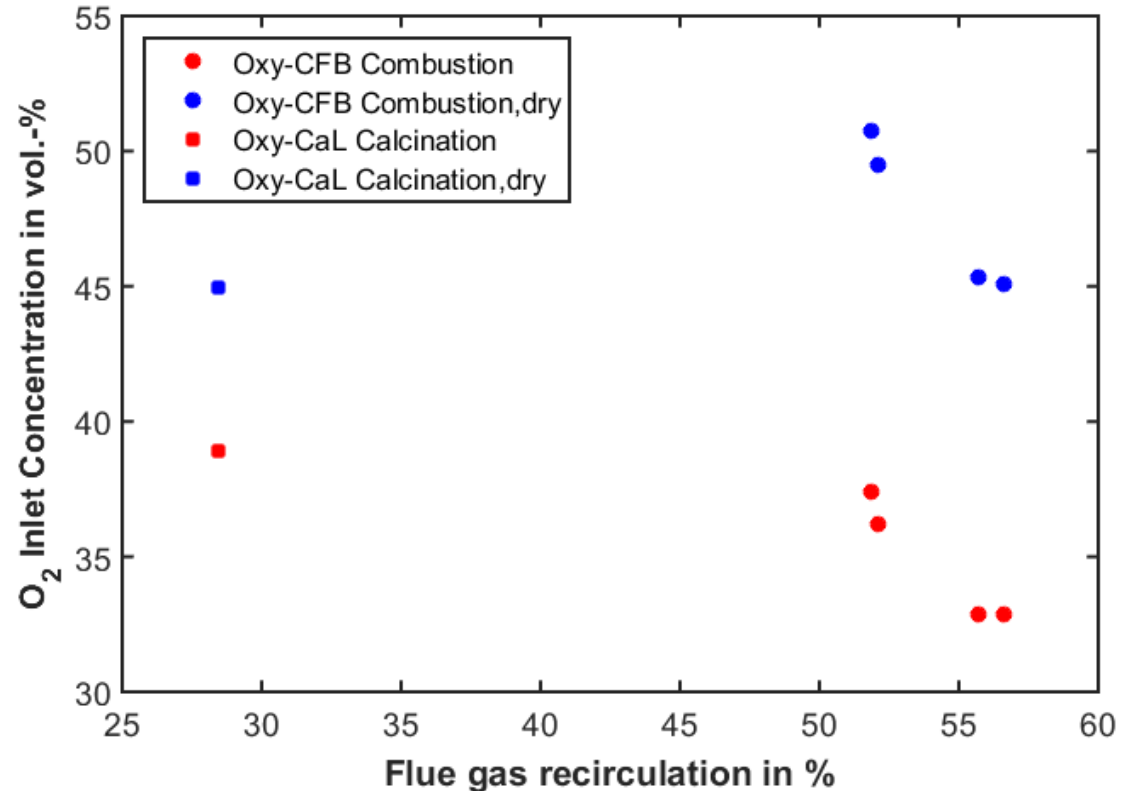


# Operational Results – Oxy-fuel Calcination



# Operational Results – Oxy-fuel Calcination

- High inlet oxygen concentrations (> 50 vol.-%, dry) possible
- lower recirculation rates for oxy-CaL calcination (additional CO<sub>2</sub> from calcination)
- lower humidity of CaL flue gas
- uniform isothermal conditions





# Calcium Looping – Pilot Plant (200 kW<sub>th</sub>)

## Operation Conditions

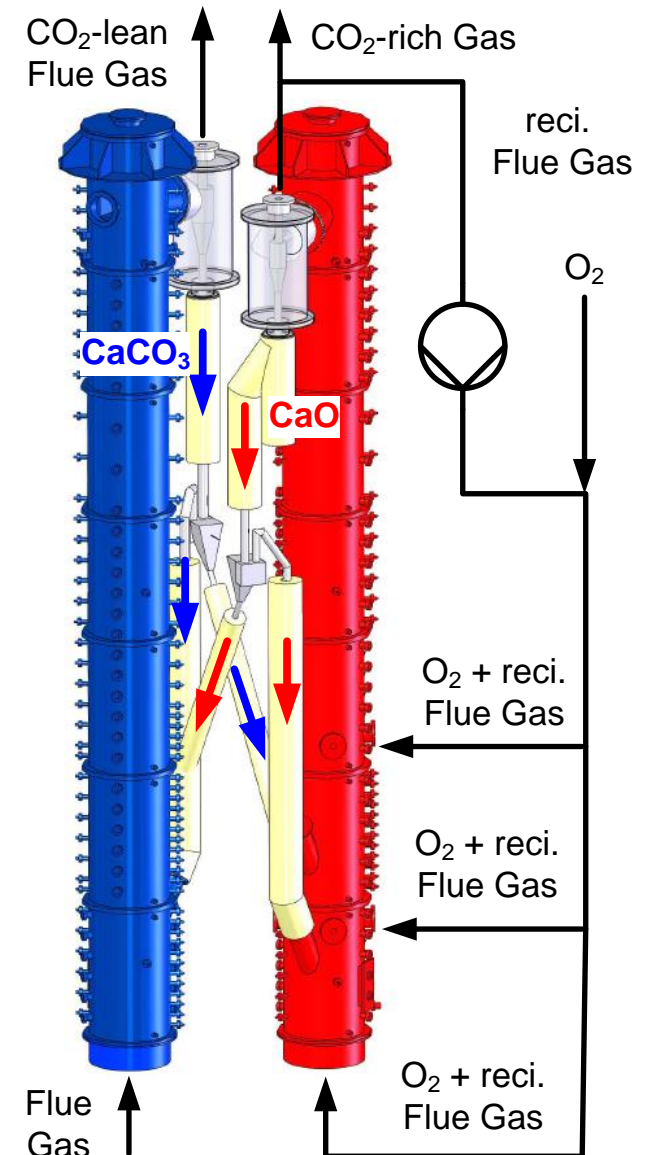
- Flue Gas Load: 170 - 230 kW<sub>th</sub>
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- Total Solid Inventory: 70 - 120 kg CaO/CaCO<sub>3</sub>

## Carbonator

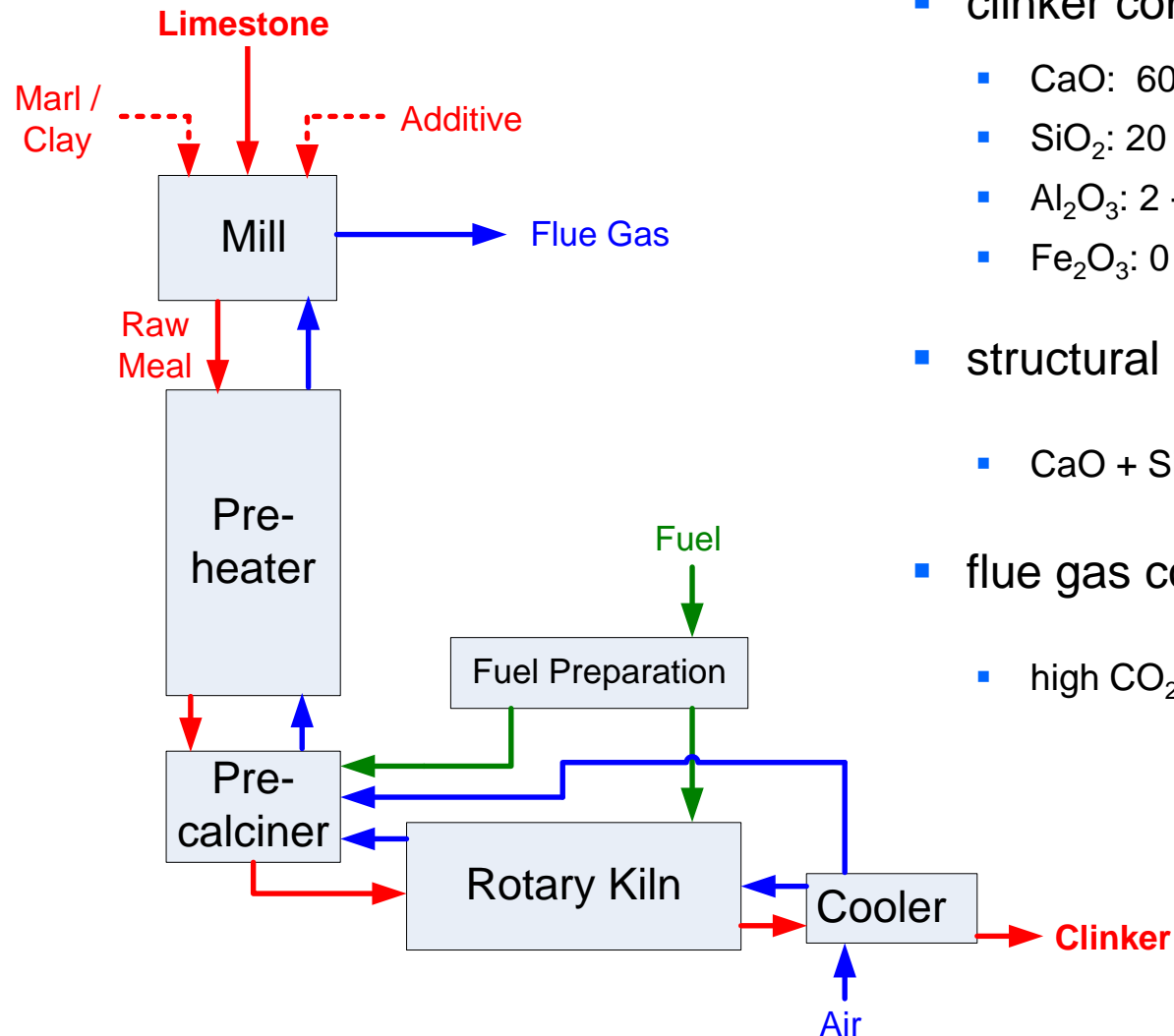
- CO<sub>2</sub> capture efficiency above 90 %

## Calciner

- CO<sub>2</sub> outlet concentrations above 90 vol.-%, dry
- Inlet O<sub>2</sub> concentrations above 50 vol.-%, dry
- Excess O<sub>2</sub> outlet concentration below 3 vol.-%, dry



# Cement Plant – Clinker Production and Properties



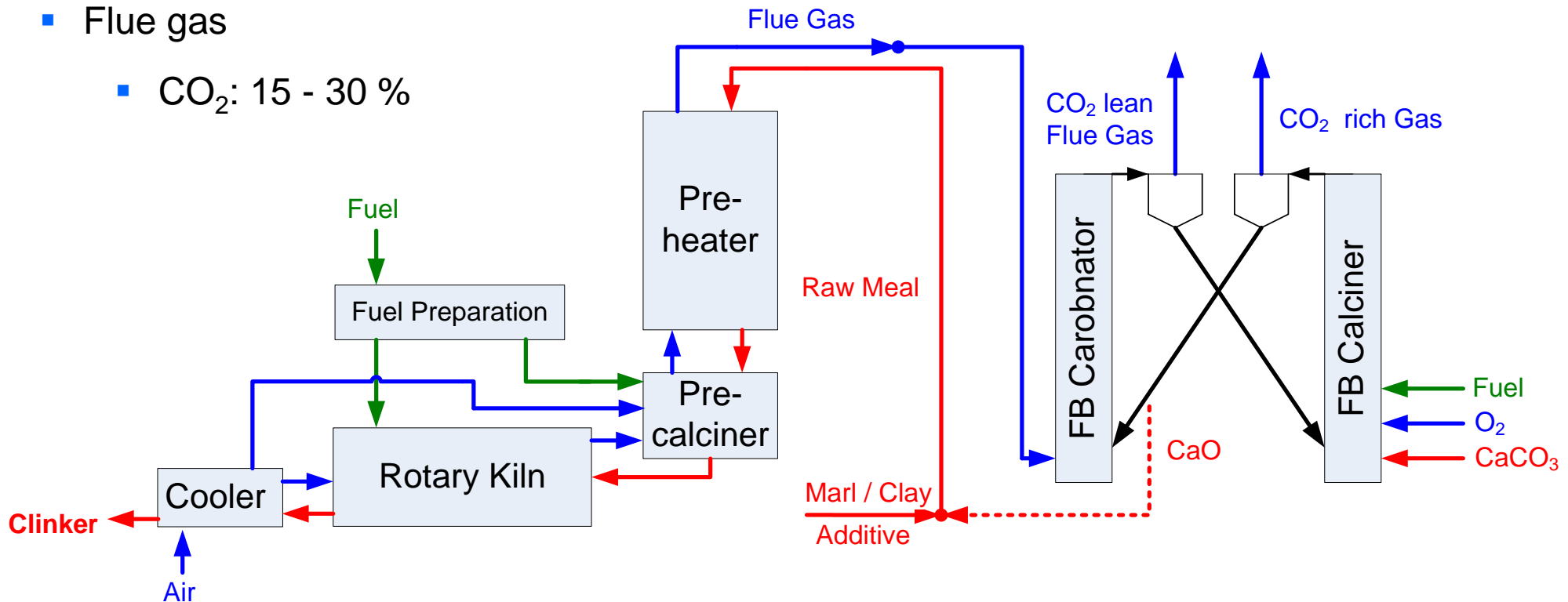
- clinker composition
  - CaO: 60 - 70 %
  - SiO<sub>2</sub>: 20 - 25 %
  - Al<sub>2</sub>O<sub>3</sub>: 2 - 6 %
  - Fe<sub>2</sub>O<sub>3</sub>: 0 - 6 %
- structural change at 1400 °C (rotary kiln)
  - $\text{CaO} + \text{SiO}_2 \rightarrow (\text{CaO})_3 \cdot \text{SiO}_2 \text{ \& \ } (\text{CaO})_2 \cdot \text{SiO}_2$
- flue gas composition
  - high CO<sub>2</sub> 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<sub>2</sub>: 15 - 30 %



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- **Calcium looping for power plant application demonstrated at pilot plant scale**
    - CO<sub>2</sub> capture efficiency over 90 %
    - CO<sub>2</sub> concentrations over 90 %
  
  - **Feasibility for cement plant application will be investigated at pilot plant scale**
    - Effect of high CO<sub>2</sub> flue gas concentration
    - Influence of make-up ratio, sorbent looping ratio
    - Optimal operation conditions

# Thank you for your attention!



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# Thank you for your interest!

## Any Questions?

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