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Demonstration of the Calcium Looping Process: High Temperature CO_2 Capture with CaO in a 200 kW_{th} Dual Fluidized Bed Pilot Facility

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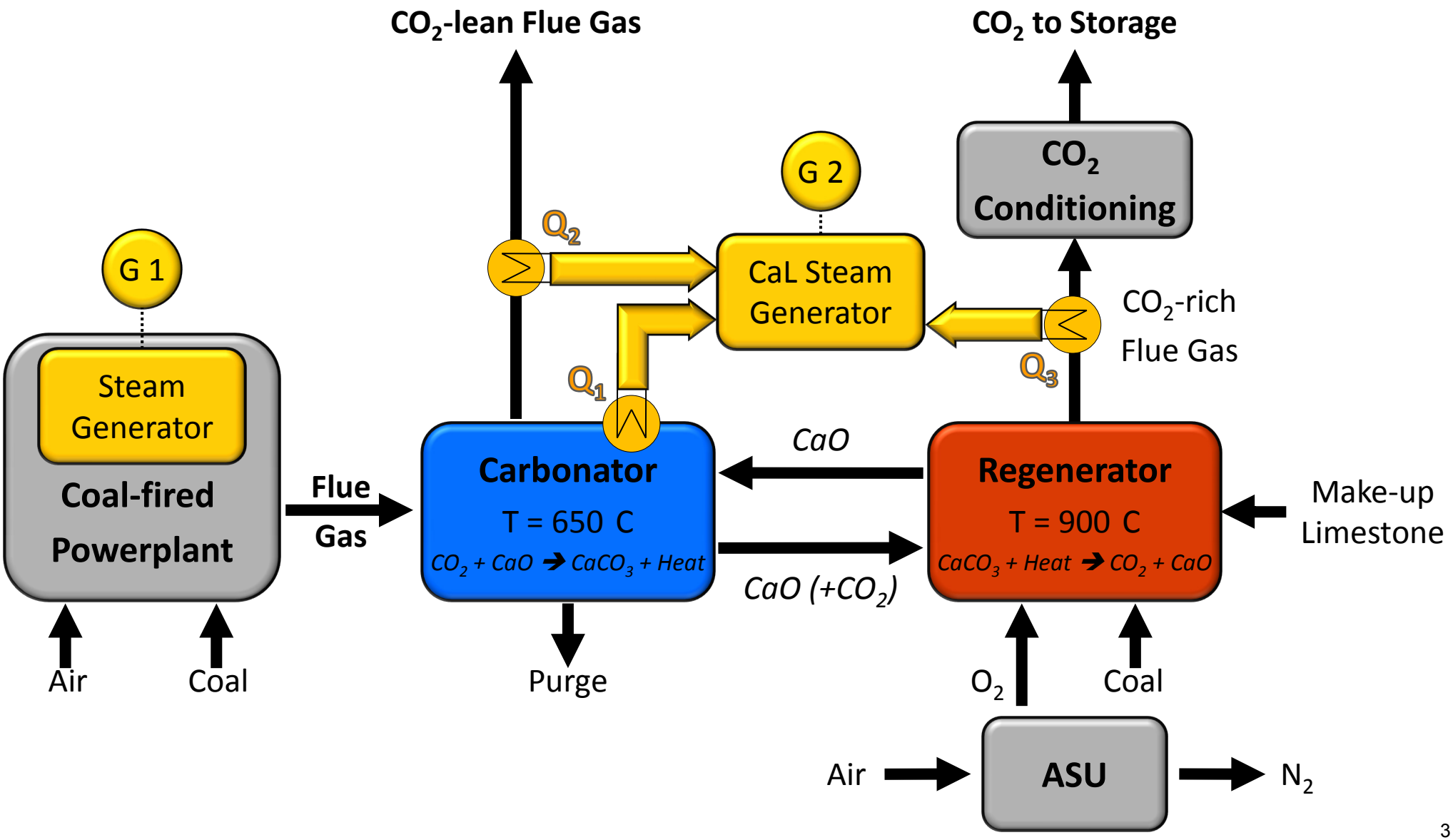
Trondheim TCCS-6 Conference, June 14-16th, 2011

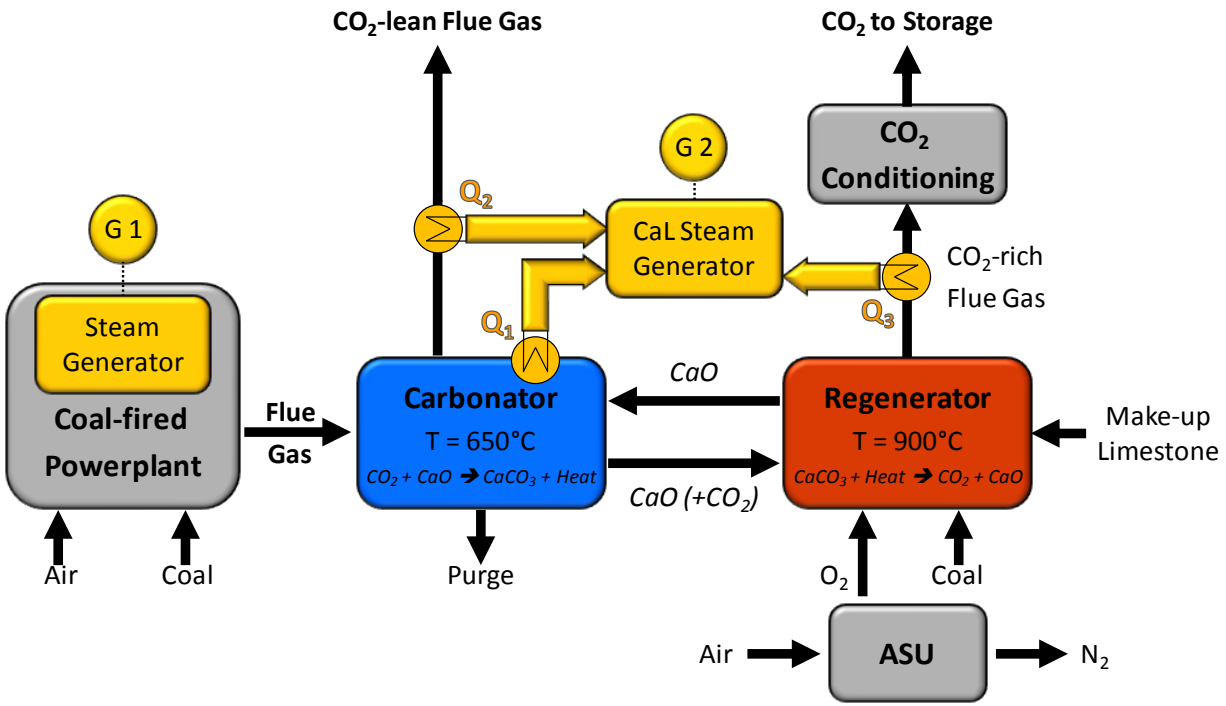
Contents

- The Calcium Looping CO_2 Capture Process
- The 200 kW_{th} Calcium Looping Pilot Plant
- Pilot Plant Results
- Conclusions and Outlook

The Calcium Looping (CaL) Process



The Calcium Looping (CaL) Process



CO_2 Capture Costs[1]:

- Over 90% CO_2 Capture efficiency demonstrated
- CO_2 Avoidance Cost ~ 20 €/t CO_2
- Cost of Electricity ~ 40 €/MWh
- Purged material can be efficiently utilized in cement or FGD processes

Electricity Generation[2]:

- Plant electric efficiency including CO_2 capture and compression calculated at 39.2%
  - 6.4% penalty
- Power output increases ~ 45%

[1] *Poboss et al., Cooretec Final Report 2008; Abanades et al., Environ. Sci. Technol., 2007*

[2] *Hawthorne et al., Energy Procedia, 2009*

R&D Calcium Looping Process Roadmap

Process Simulation & Cost Calculations

Hawthorne et al., Poboss et al., Abanades et al.

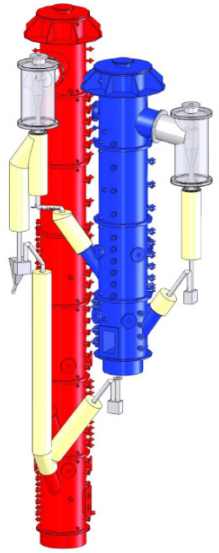
TGA Sorbent Characterisation

Grasa et al.

Process Characterisation

Electr. heated
10 kW_{th} facility

Charitos et al., Abanades et al.



Process Demonstration:

Realistic Process Conditions

- No external heating
- Real Flue Gas
- Oxyfuel Calcination
- Coal influence (S, ash)

Shimizu et al. 1999

Process Idea

Labscale

Process Simulation

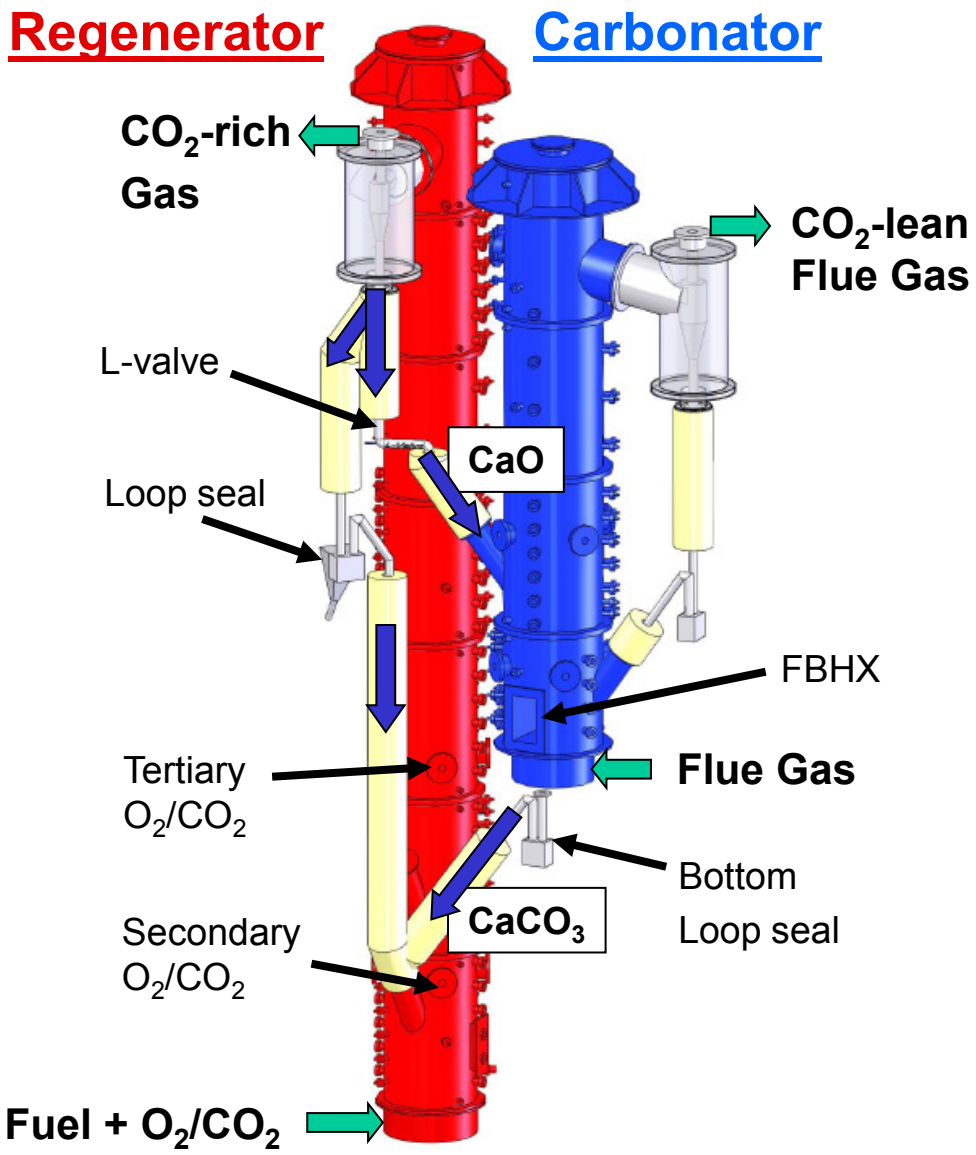
10 kW_{th} – DFB Facility

200 kW_{th} - Pilot Plant Process Demonstration

Demo Plant

Commerical Plant

200 kW_{th} DFB Calcium Looping Plant



Carbonator:

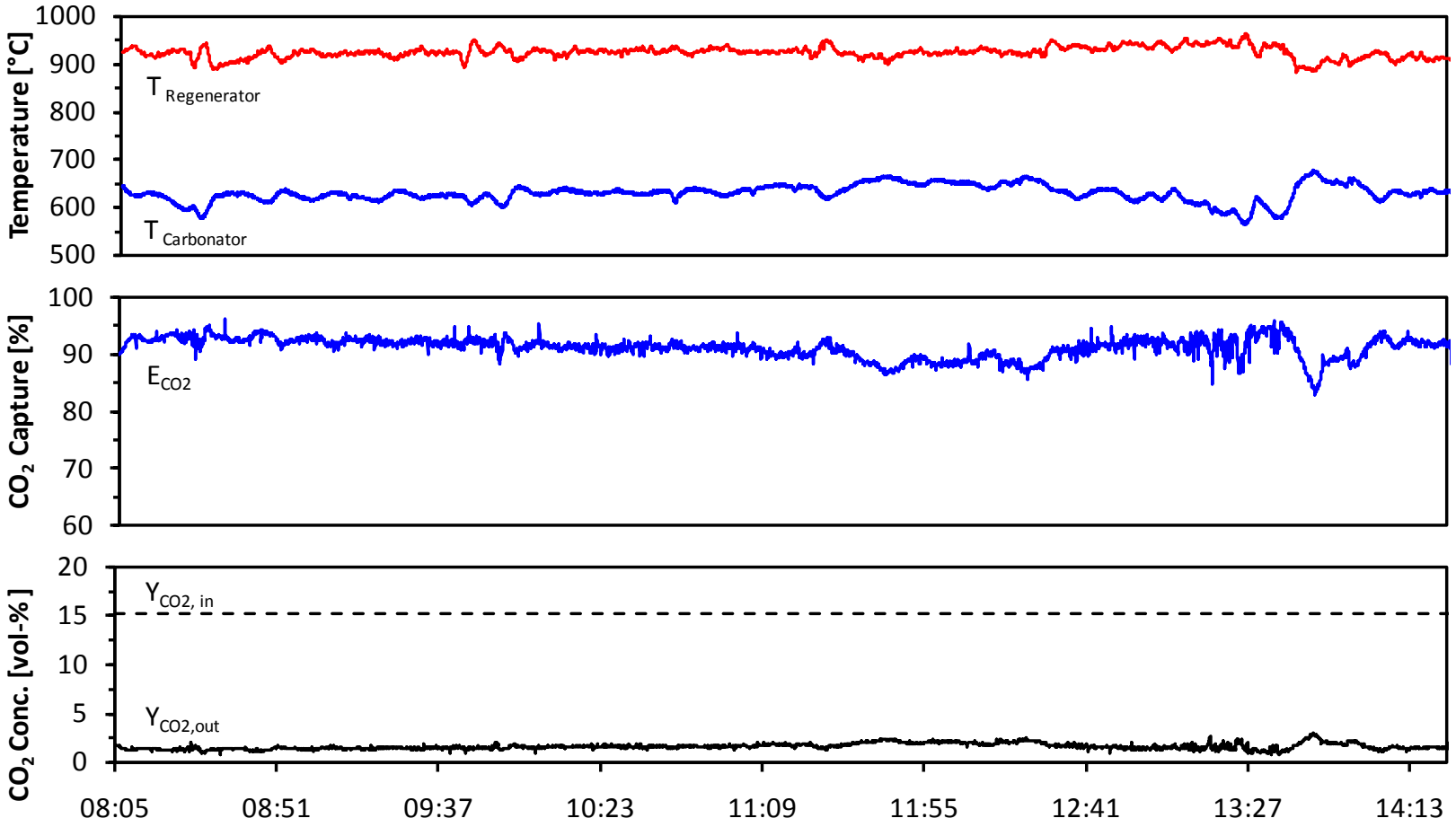
- Turbulent CFB Reactor
- Good gas-solid contact
- Lower entrainment than fast fluidized CFB
- Looping Rate controlled by L-valve
- Bottom loop seal regulates bed inventory
- Temperature controlled by Looping Rate and Fluidized Bed Heat Exchanger

Regenerator:

- Fast fluidized CFB calciner
- Temperature controlled by oxy-combustion

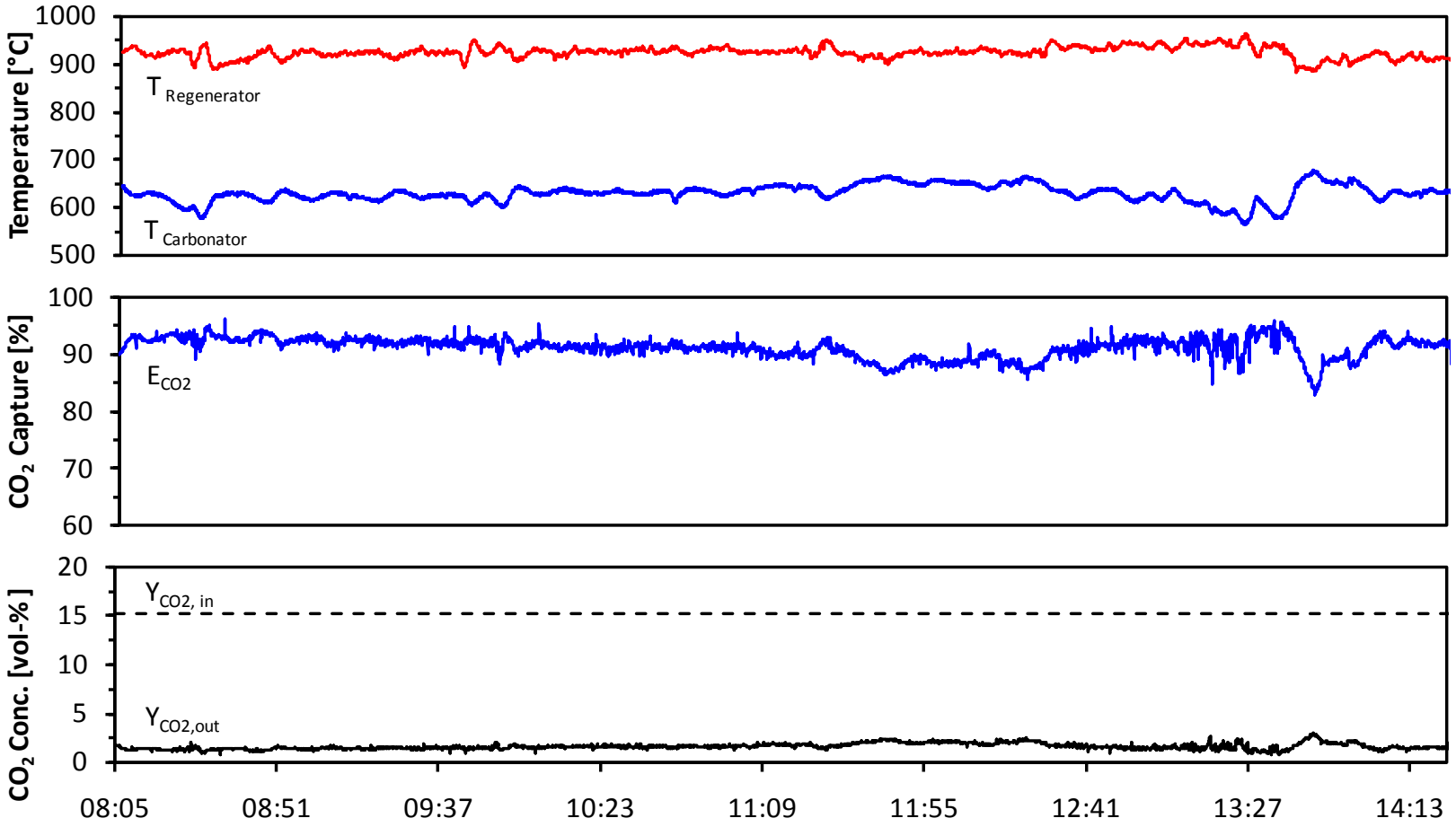
Overview of Pilot Plant Operation

- 3 measurement campaigns completed with over 300 h of successful operation
- Dual Fluidized Bed system proved flexible and robust
  - Operated over a wide range of temperatures and looping rates
  - L-valve & loop seal system delivers stable sorbent looping rate

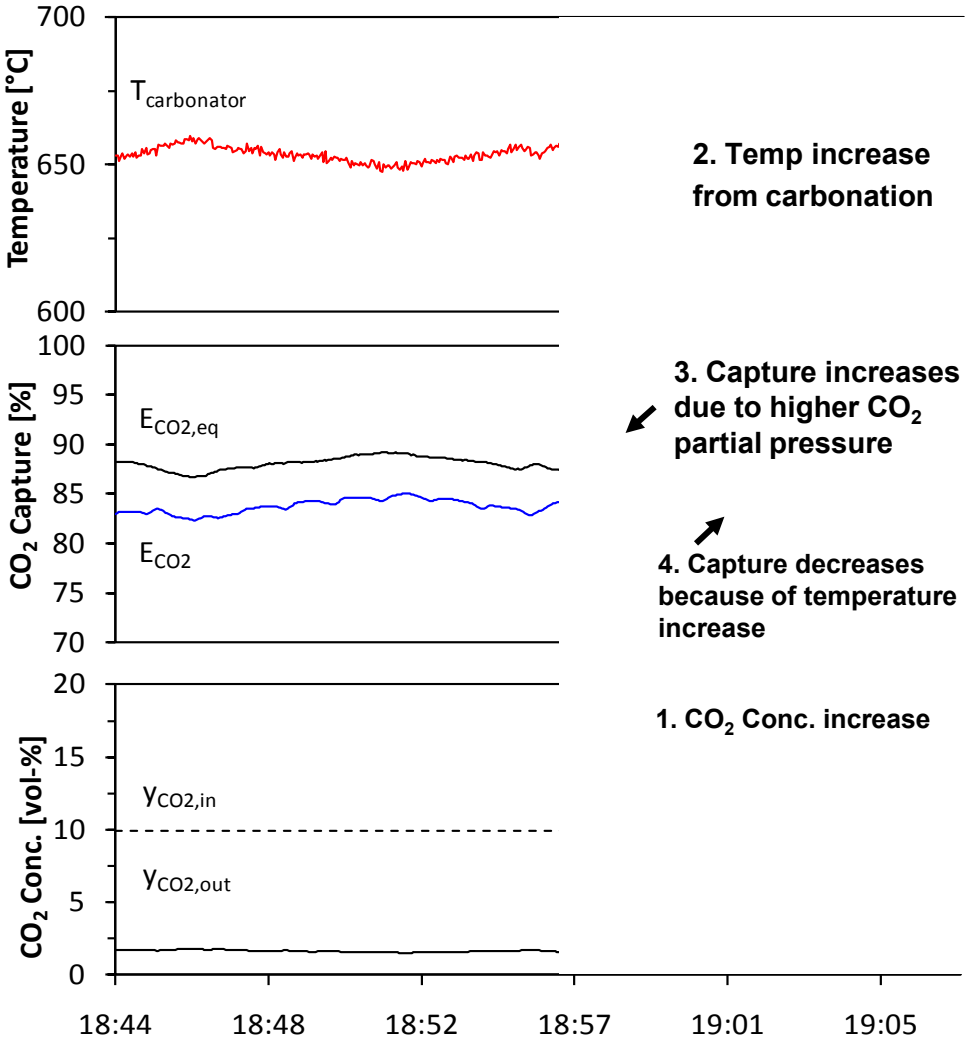


Overview of Pilot Plant Operation

- **Over 90% capture efficiency** achieved over a wide range of operating conditions
- Oxyfuel Regenerator performed well as a combustor:
  - High fuel burnout (low CO), good controlability and uniform temperature profiles
  - Complete calcination of incoming carbonated sorbent and make-up $CaCO_3$



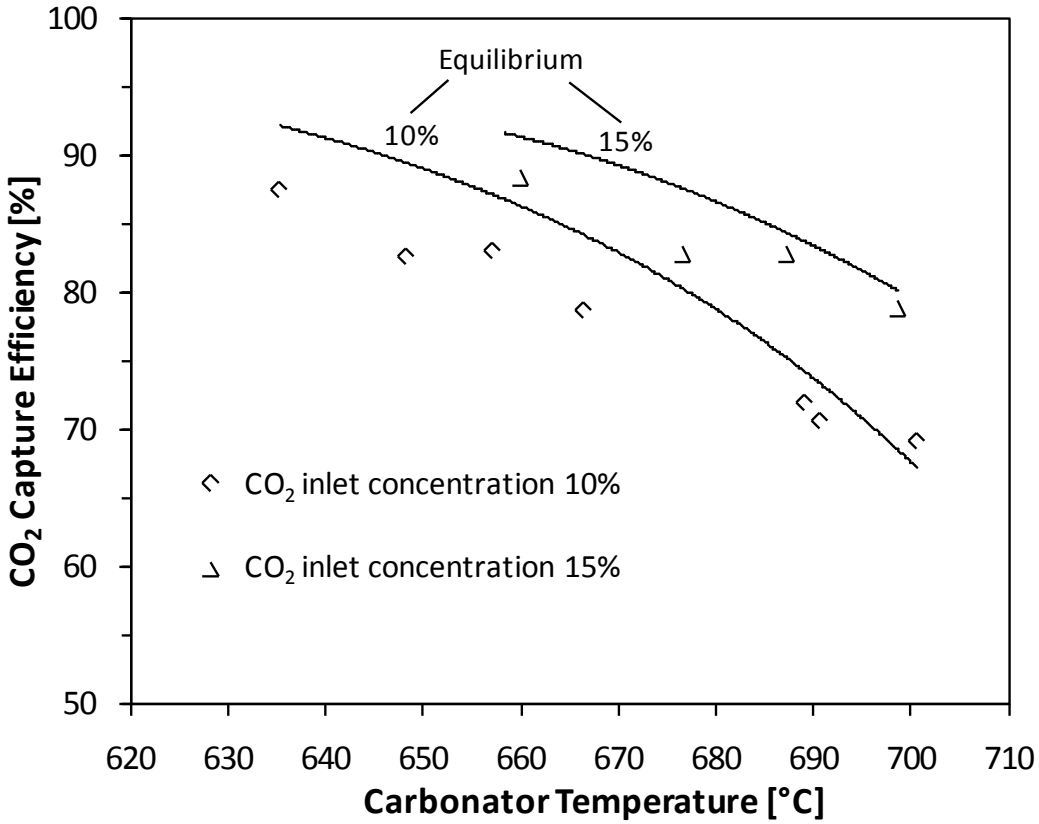
System Response: Change in Inlet CO_2 Conc.



Pilot plant operates as designed:

- Facility responds quickly to set point changes, e.g. inlet CO_2 vol.-% concentration
- Capture efficiencies are constant over time once system stabilized
- CO_2 capture close to equilibrium

Results Summary: Effect of Temperature



Every data point is a steady state where

- Solid samples taken & analyzed
- Circulation rate measured
- CO_2 capture measured

All capture efficiencies are close to maximum equilibrium value

Highest CO_2 capture achieved between 635-660°C for inlet concentrations of 10-15 Vol.-% CO_2

➢ **Over 90% capture efficiency in steady state pilot operation**

Ref: Hawthorne and Dieter, High Temperature CO_2 Capture with CaO in a 200 kW_{th} Dual Fluidized Bed Pilot Facility. 2nd Efficient Carbon Capture for Coal Power Plants, June 2011.

Conclusions and Outlook

Calcium Looping process successfully demonstrated on a 200 kW_{th} pilot facility:

- CO_2 capture efficiency over 90 % achieved
- Plant showed robust performance and flexibility over 300 h of operation
- Full sorbent calcination in oxy-fired regenerator achieved
- Low sorbent loss due to attrition, i.e. ~ 5 wt.% bed/h

Recently obtained results and upcoming R&D topics:

- Influence of Make-up and steam content in flue gas on CO_2 capture efficiency
  - Tests completed and will be published in the near future
- Influence of sulfur and coal ash on sorbent activity and pilot operation

Acknowledgements

The results from the 200 kW_{th} Calcium Looping pilot plant were produced as part of a joint university-industrial research & development project funded by EnBW Kraftwerke AG.