

---

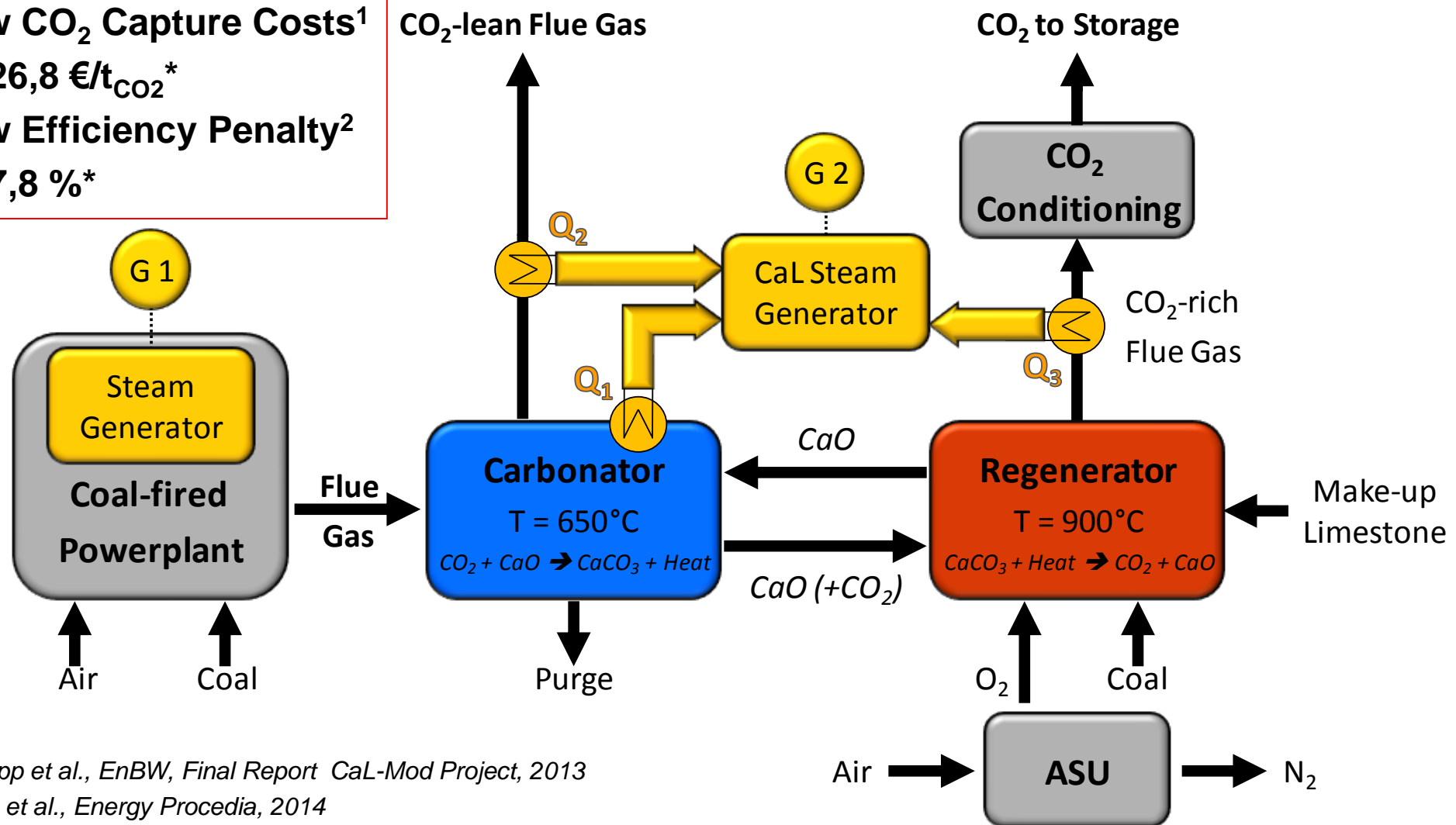
# Calcium Looping Post Combustion CO<sub>2</sub> Capture: A promising technology for emission free cement production

*Heiko Dieter*

Trondheim, TCCS 8, June 18<sup>th</sup>, 2015

# The Calcium Looping Process for Power Plants

Low CO<sub>2</sub> Capture Costs<sup>1</sup>  
 → 26,8 €/t<sub>CO<sub>2</sub></sub>\*  
 Low Efficiency Penalty<sup>2</sup>  
 → 7,8 %\*



<sup>1</sup> Schaupp et al., EnBW, Final Report CaL-Mod Project, 2013

<sup>2</sup> Dieter et al., Energy Procedia, 2014

\* Including compression

# R&D Roadmap Calcium Looping Process

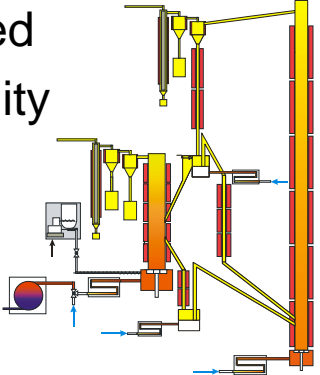
**Process Simulation & Cost Calculations**  
 Hawthorne et al., Poboss et al., Abanades et al.

**TGA Sorbent Characterisation**  
 Grasa et al.



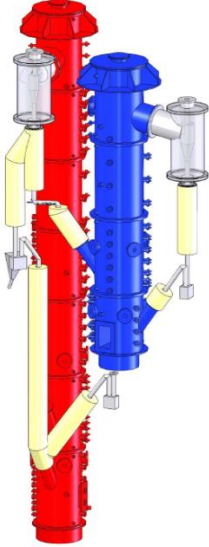
**Process Characterisation**  
 Electr. heated  
 10 kW<sub>th</sub> facility

Charitos et al.,  
 Abanades et al.

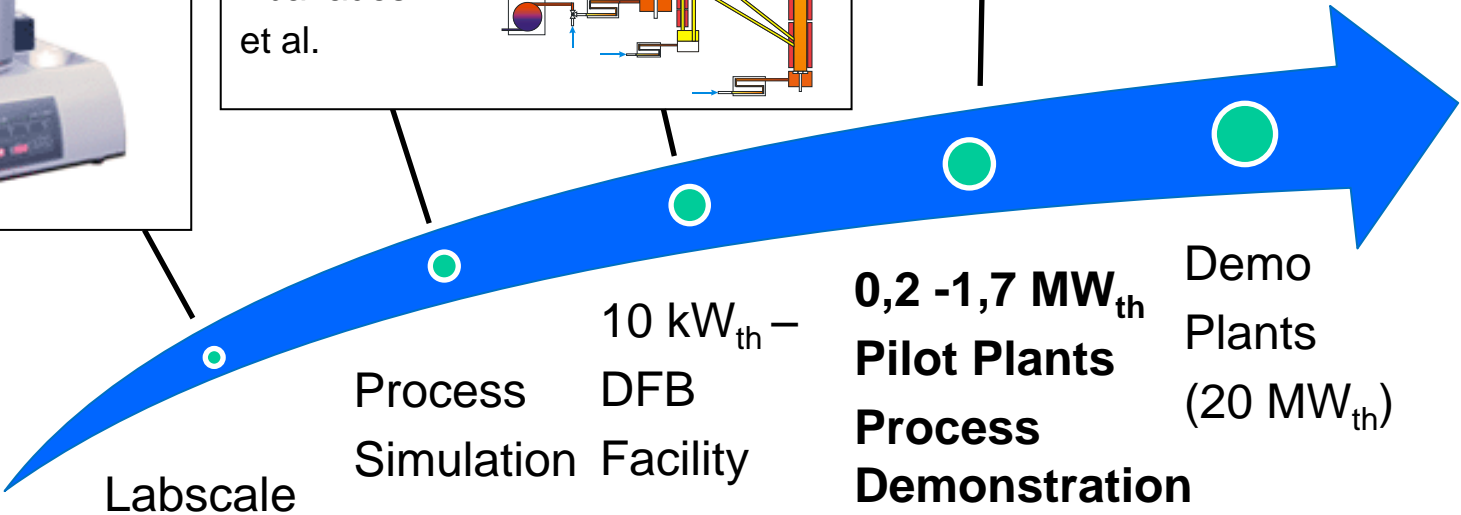


**Process Demonstration:**  
 Realistic Process Conditions

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



Shimizu et al. 1999



Commerical Plant

Process Simulation Facility  
 10 kW<sub>th</sub>

**0,2 -1,7 MW<sub>th</sub> Pilot Plants Process Demonstration**

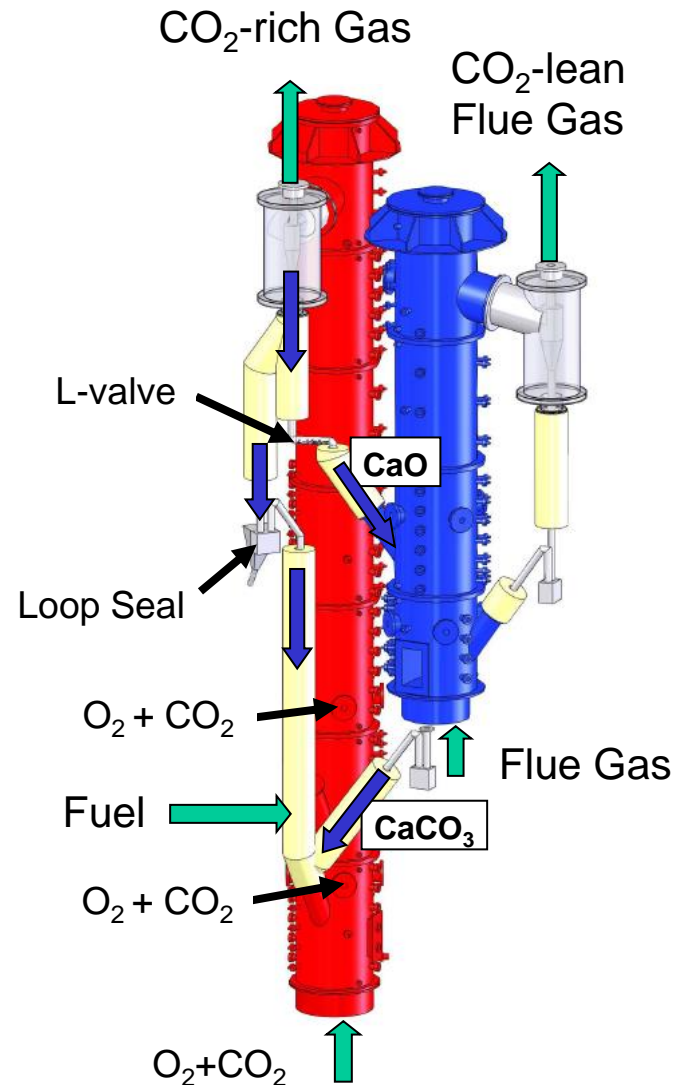
Demo Plants (20 MW<sub>th</sub>)

Process Idea

# The 200 kW<sub>th</sub> Calcium-Looping Pilot Plant

## Turbulent Carbonator

- High flue gas load flexibility
- BFB-TFB-CFB
- No entrainment required for solid circulation
- Plant sizes < 200 MW<sub>th</sub>



## Operating Window

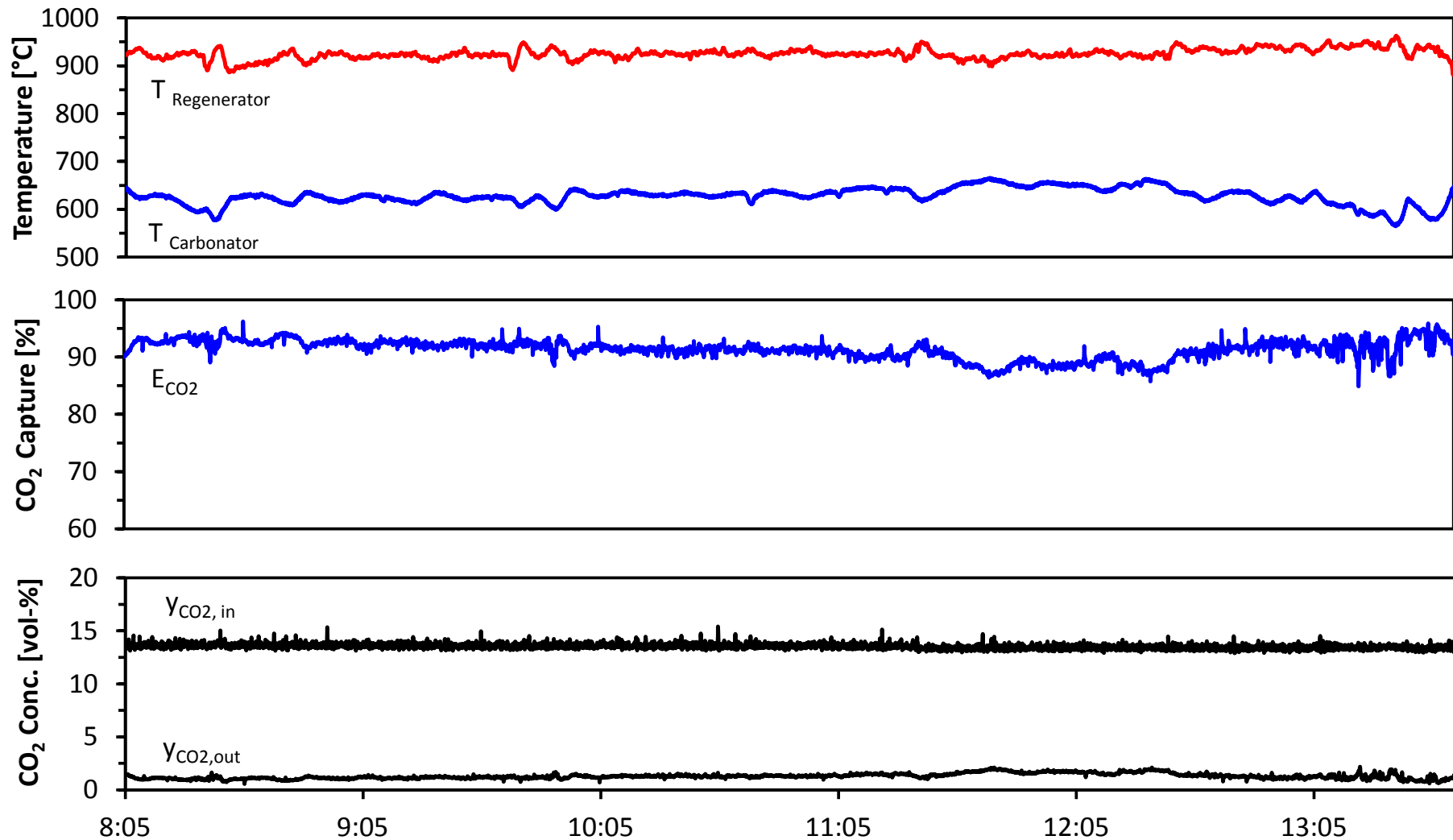
Flue Gas Load:  
50 - 200 kW<sub>th</sub>

Sorbent Looping Ratio:  
3-13 mol<sub>CaO</sub>/mol<sub>CO<sub>2</sub></sub>  
(≈ 100-1000 kg<sub>Ca</sub>/h)

Total Solid Inventory:  
70-120 kg CaO/CaCO<sub>3</sub>

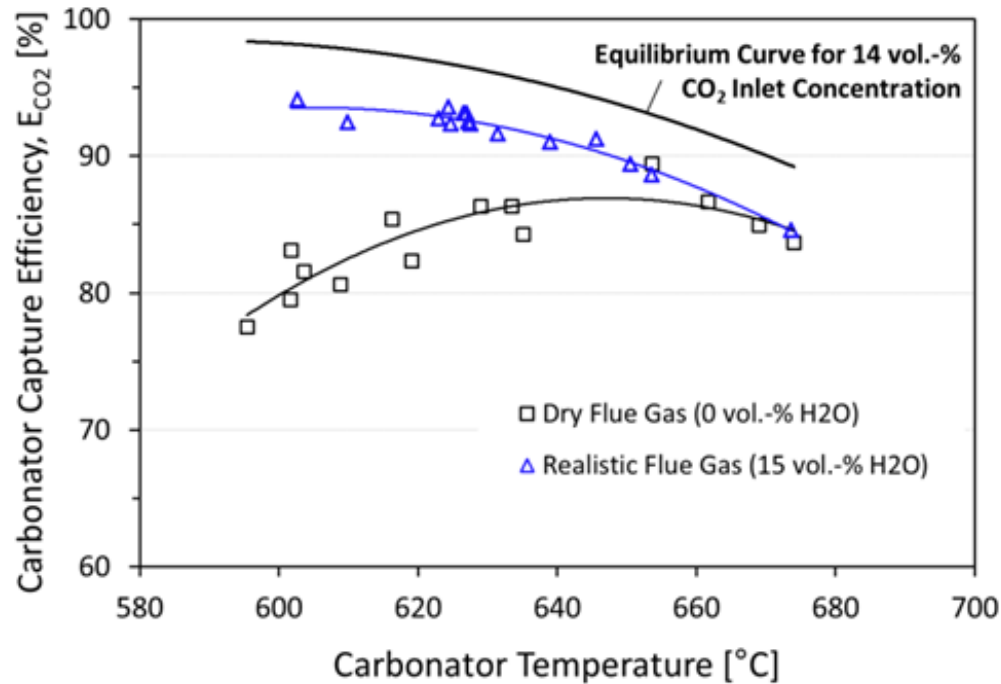
# Pilot Plant operational results

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

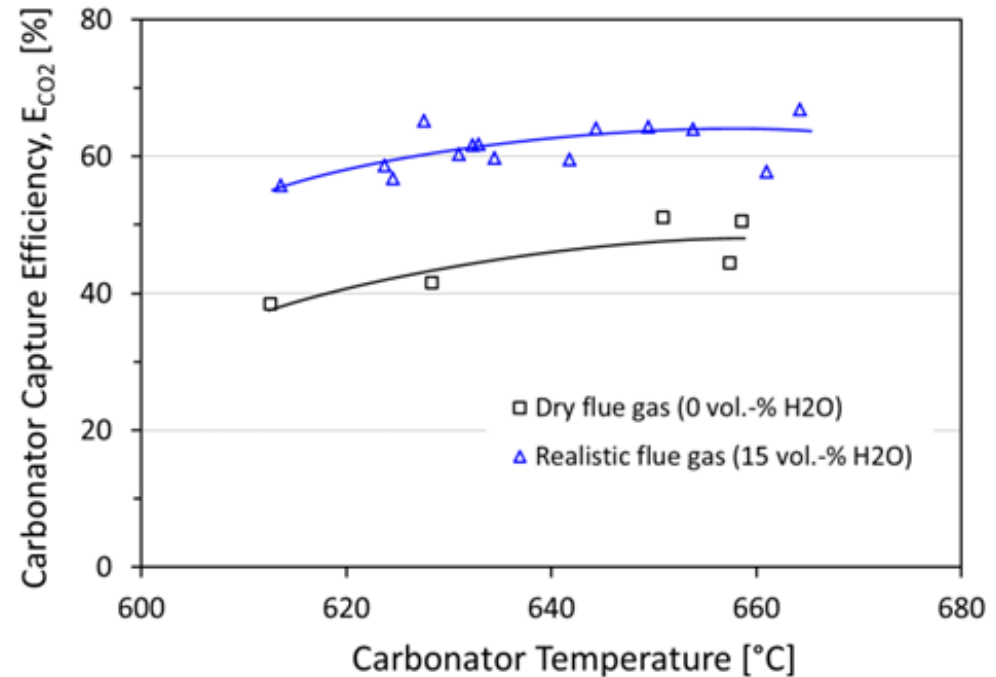


# Effect of water vapor in real flue gas

- Capture efficiencies for real flue gas close to chemical equilibrium

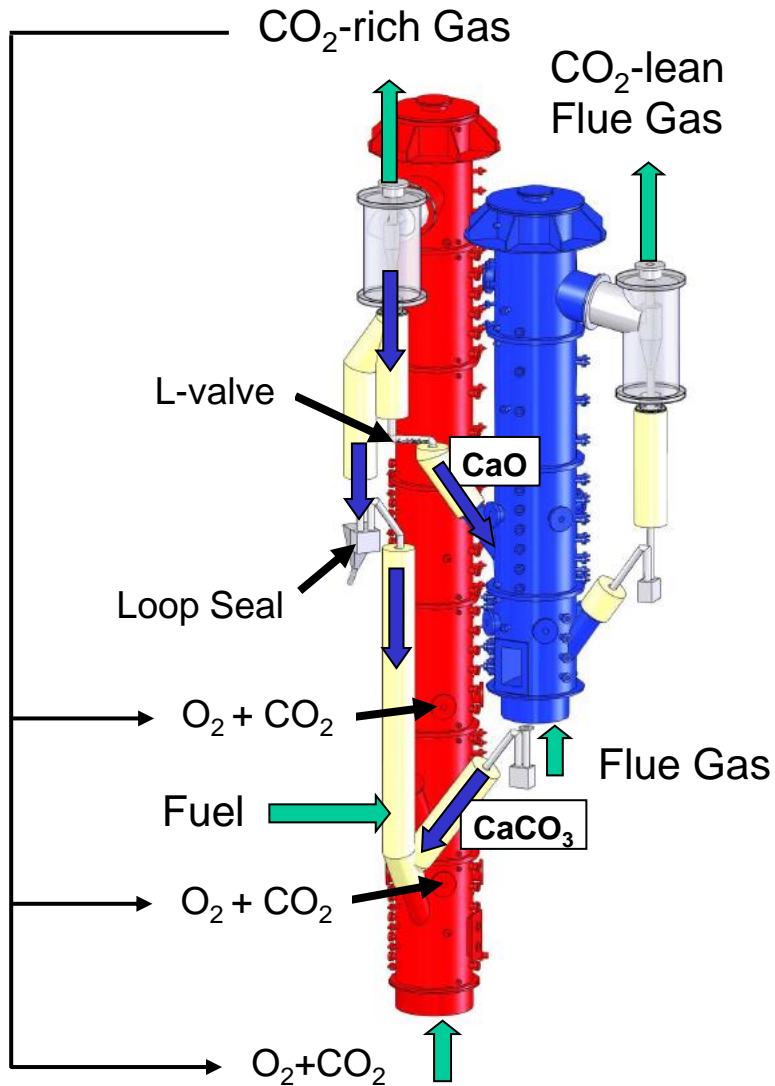


- Improvement potential with real flue gas up to 60 % identified in pilot experiments



⇒ Efficiency potential identified with real flue gas incl. water vapor (15 vol.-%)

# Calciner performance at oxy-fuel combustion

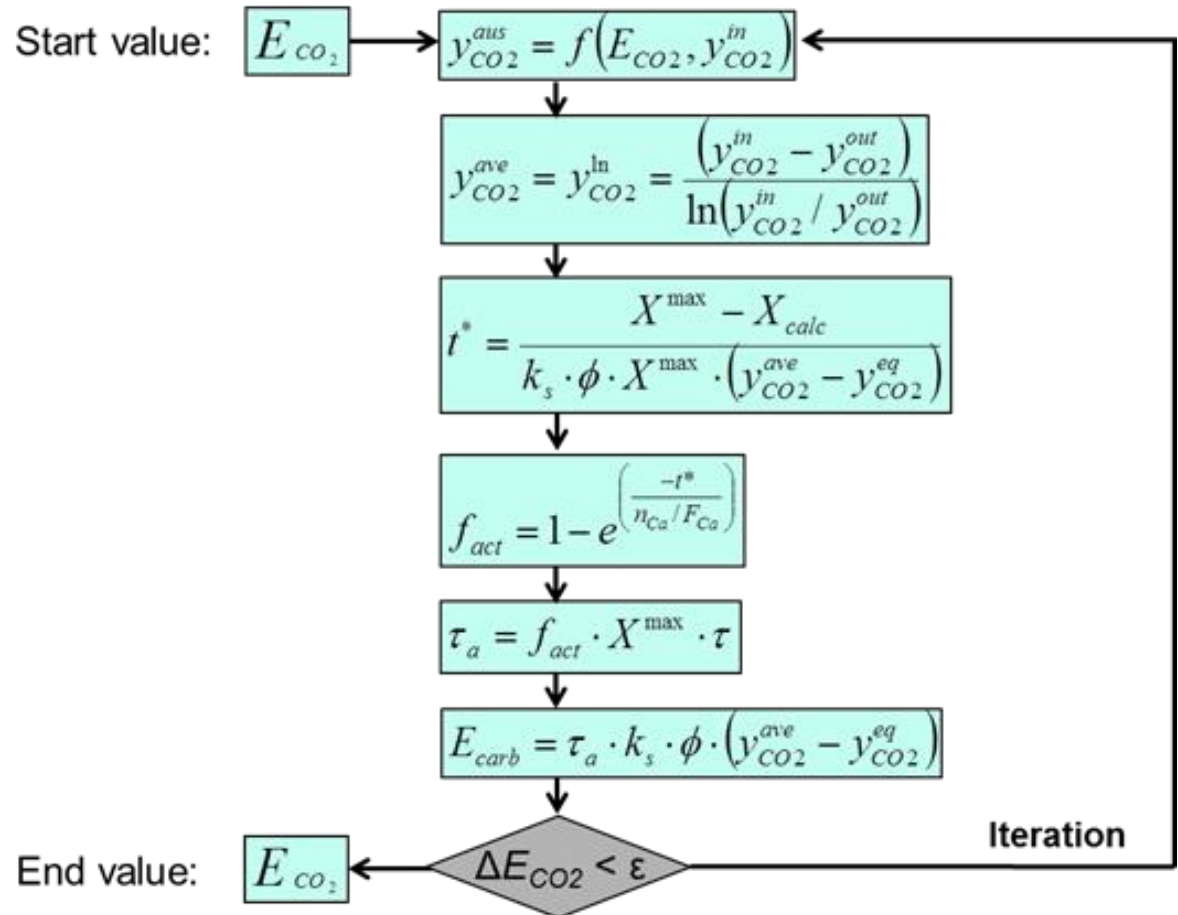


- Successful oxy-fuel regeneration with flue gas recycle
- Full calcination of sorbent
- Calciner  $\text{CO}_2$  outlet concentrations above 90 vol.-%,dry
- Excess  $\text{O}_2$  outlet concentrations below 3 vol.-%,dry
- Inlet  $\text{O}_2$  concentrations above 50 vol.-%,dry without temperature peaks in the riser

# Simulation of process efficiency

## CO<sub>2</sub> capture model:

- Implemented in ASPEN Plus<sup>®</sup> Simulation
- Prediction of CO<sub>2</sub> capture efficiency
- Validated with data from pilot scale experiments

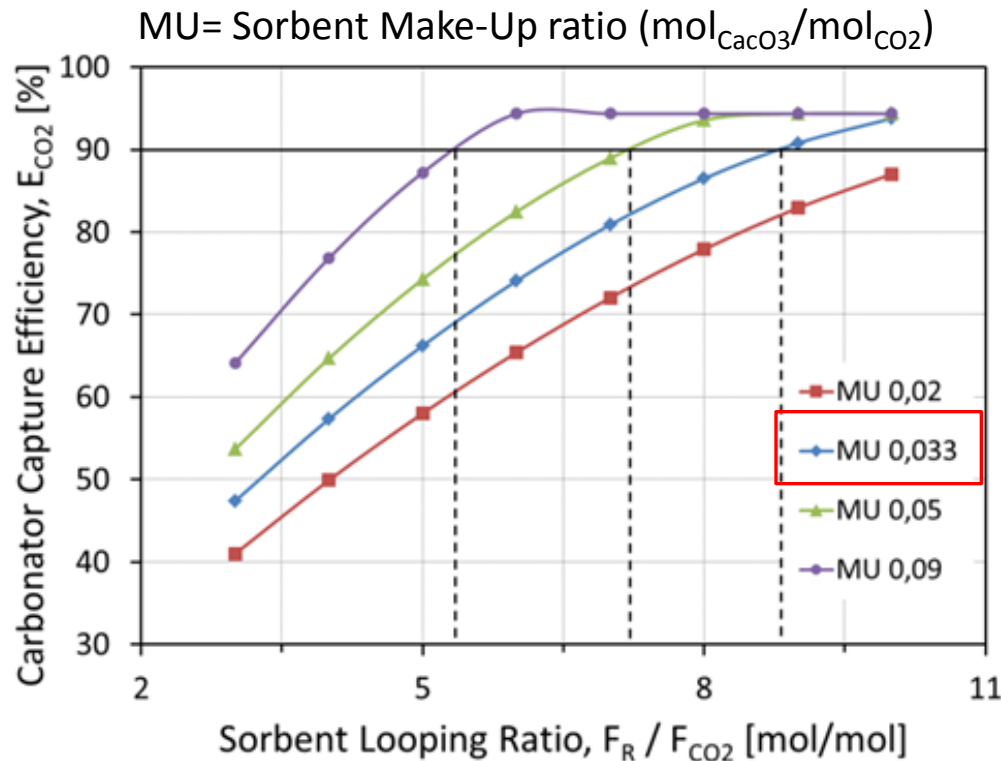


⇒ Used for process optimization and identification of efficiency potential

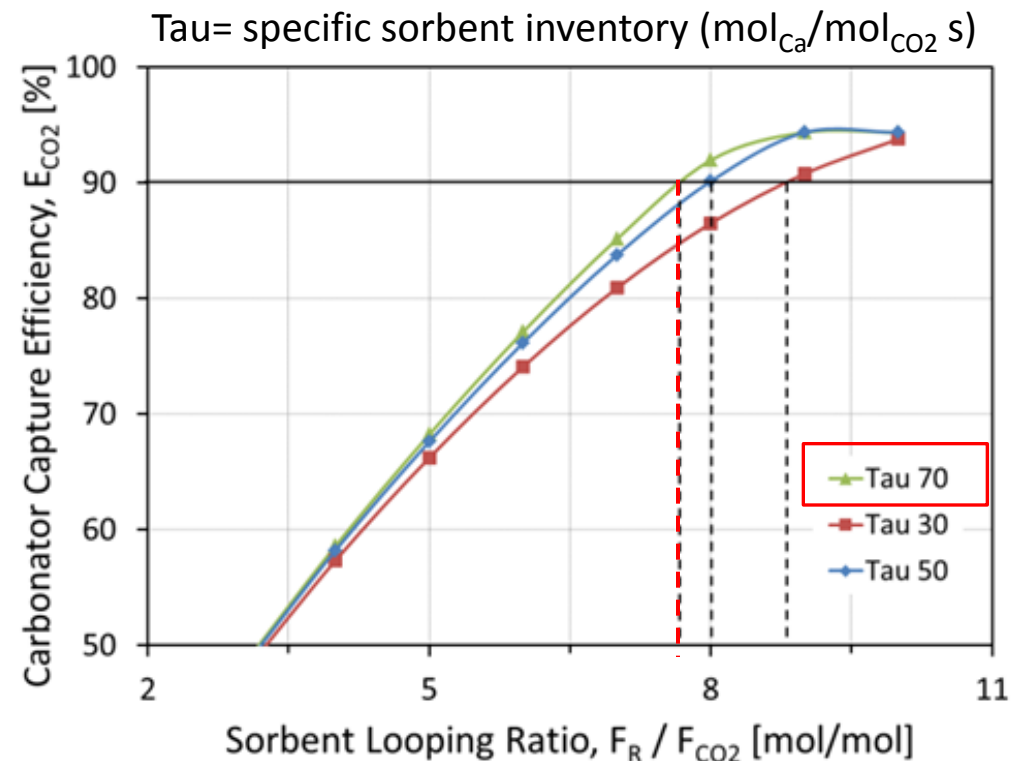


# Process optimization by simulations

- Identification of minimum required sorbent make-up ratio

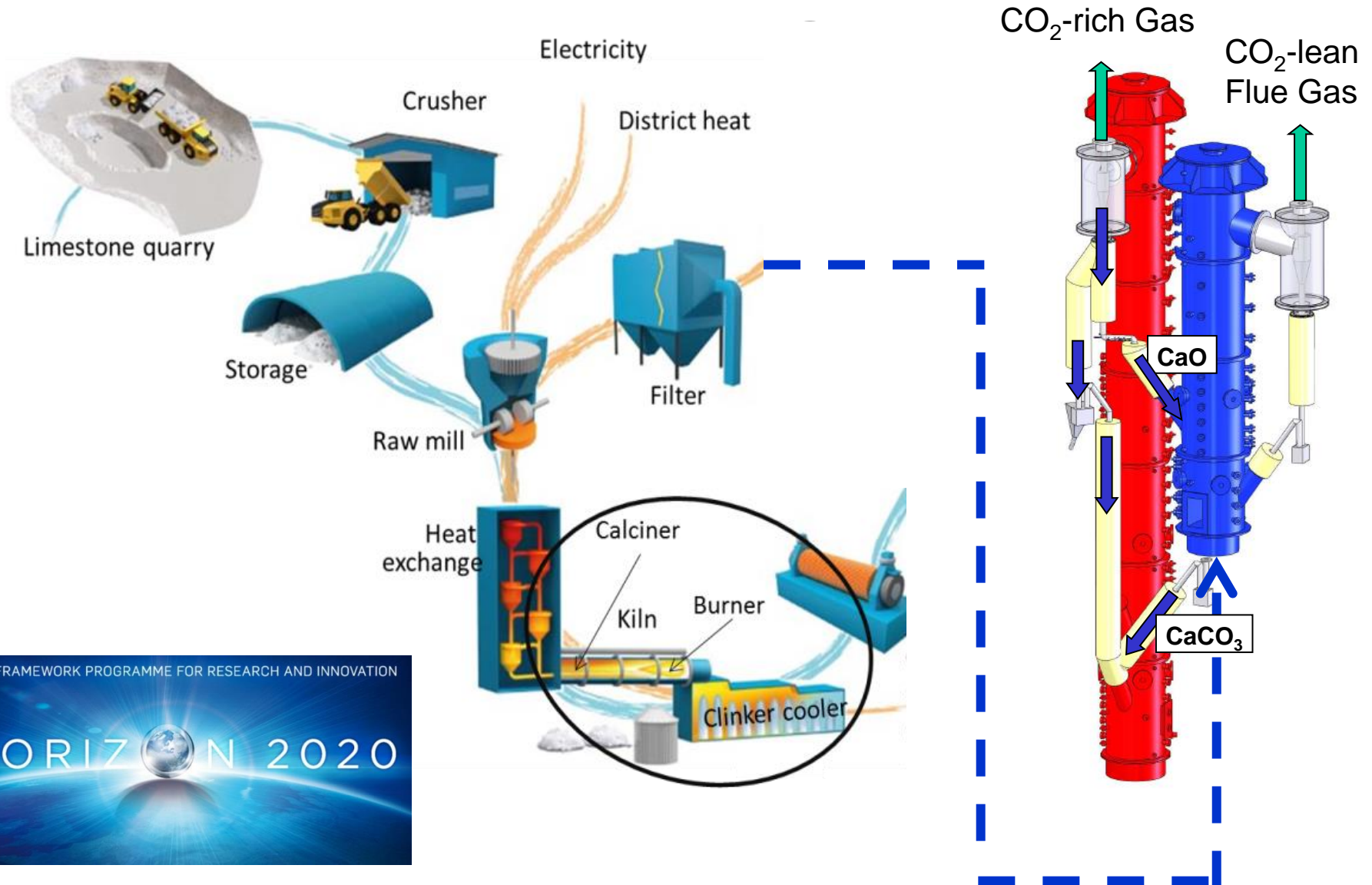


- Optimization of looping ratio to save fuel for calcination



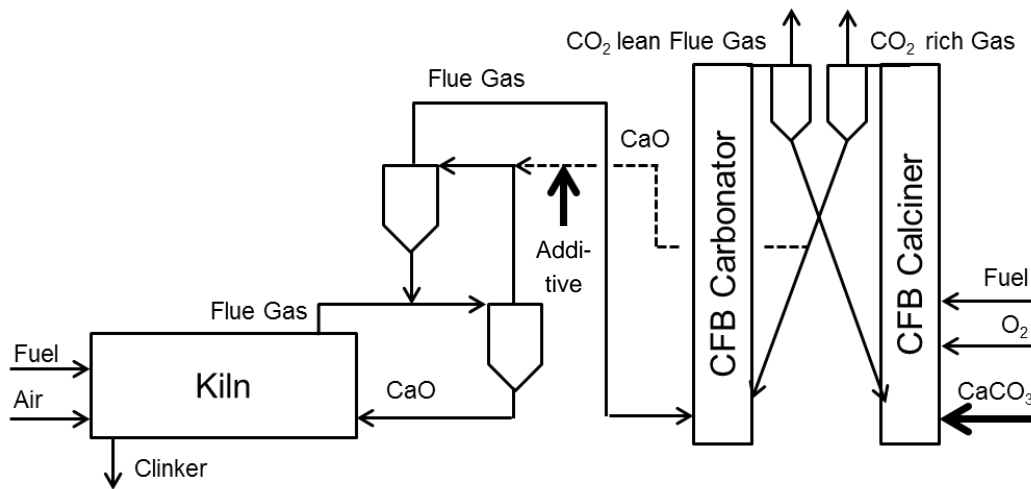
⇒ Design tool to identify optimum operating points by process simulations

# The Horizon 2020 project CEMCAP



# Goals of CEMCAP

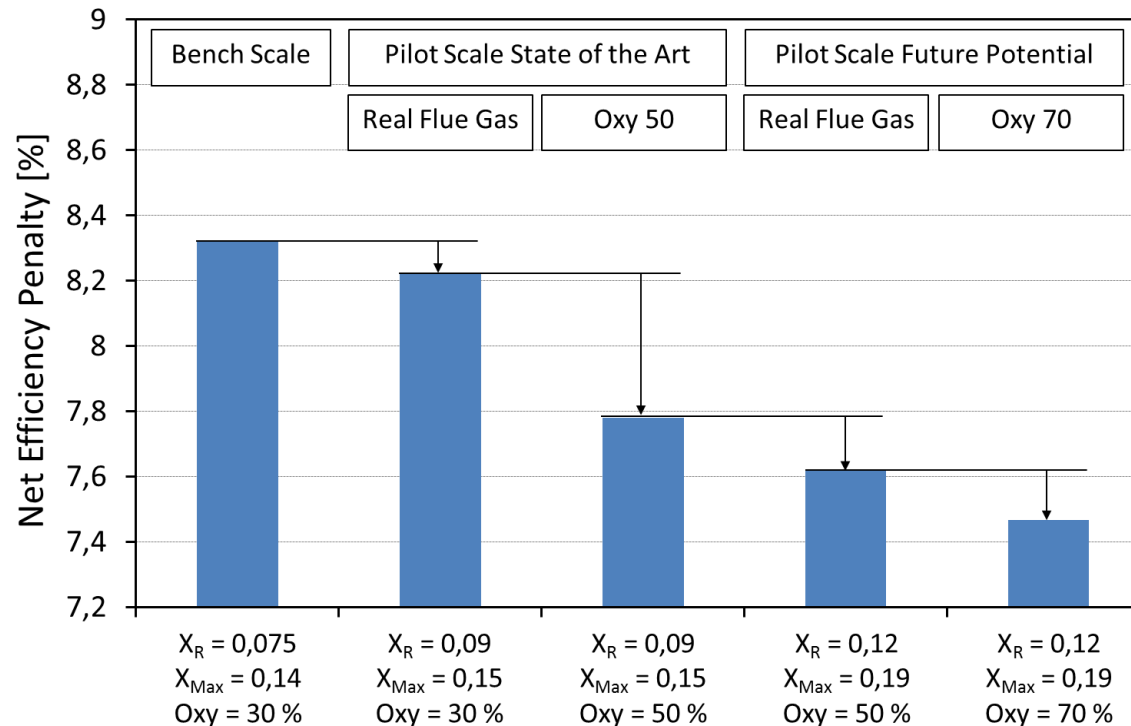
- Demonstration of Calcium Looping post combustion capture for cement
- Optimization of operating and process conditions
- Development of an integrated Calcium Looping cement process



Calcium Looping Post combustion capture

# Summary

- Calcium Looping successfully demonstrated at pilot scale for power plants
- Validated process model developed as process design tool for scale up

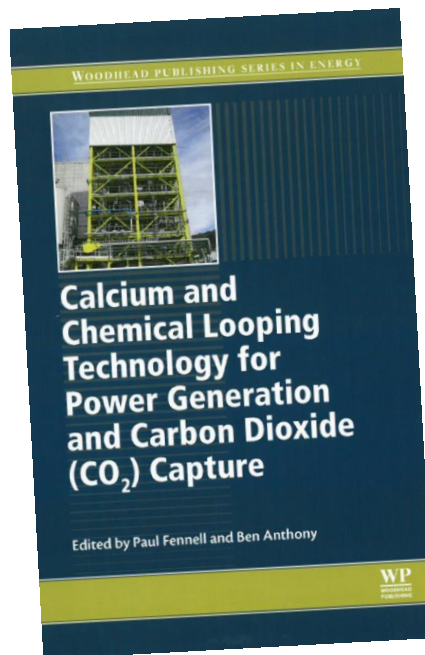


## Next steps:

- Demonstration and optimization of Calcium Looping for cement application

# Thank you for your interest!

This demonstration work at pilot scale was conducted within a joint university-industrial research & development project funded by EnBW Energie Baden-Württemberg AG and the European project CaL-Mod funded by the Research Fund for Coal and Steel (RFCS-2010-00013).

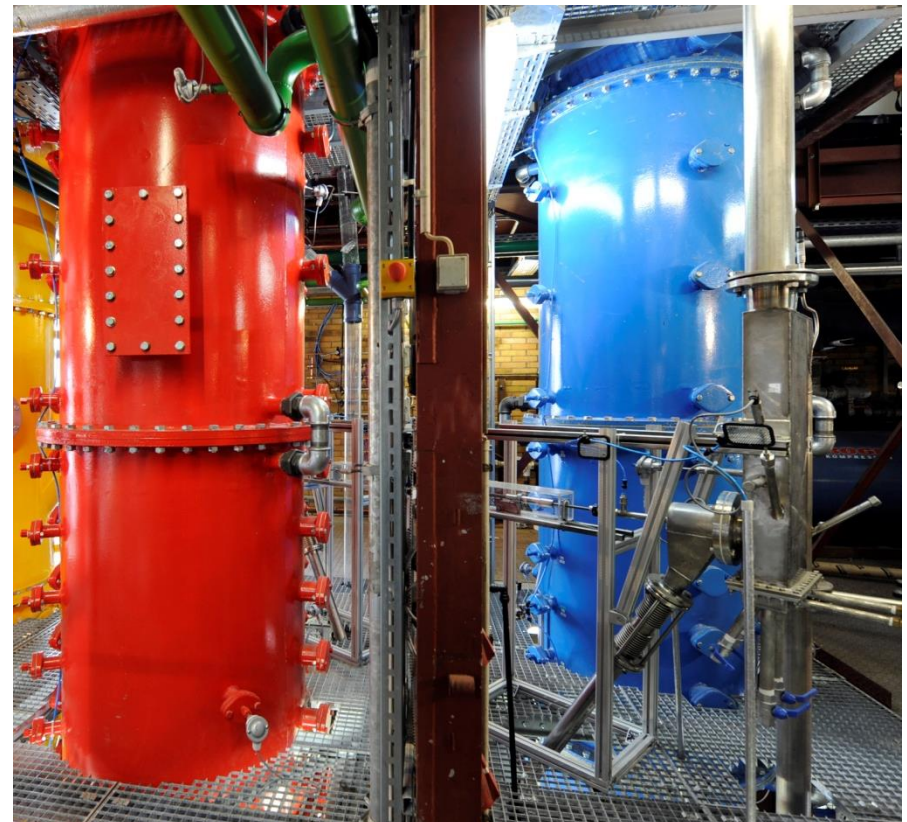


Contact:

Heiko Dieter

Institute of Combustion and Power Plant Technology,  
University of Stuttgart

[heiko.dieter@ifk.uni-stuttgart.de](mailto:heiko.dieter@ifk.uni-stuttgart.de)



# Thank you for your attention!



## Acknowledgement

This presentation was enabled by funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 641185

[www.sintef.no/cemcap](http://www.sintef.no/cemcap)

Twitter: @CEMCAP\_CO2

***Disclaimer:** The European Commission support for the production of this publication does not constitute endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein*