2nd public SCARLET workshop
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An introduction to the CEMCAP project

Kristin Jordal
SINTEF Energy Research
Kristin.Jordal@sintef.no

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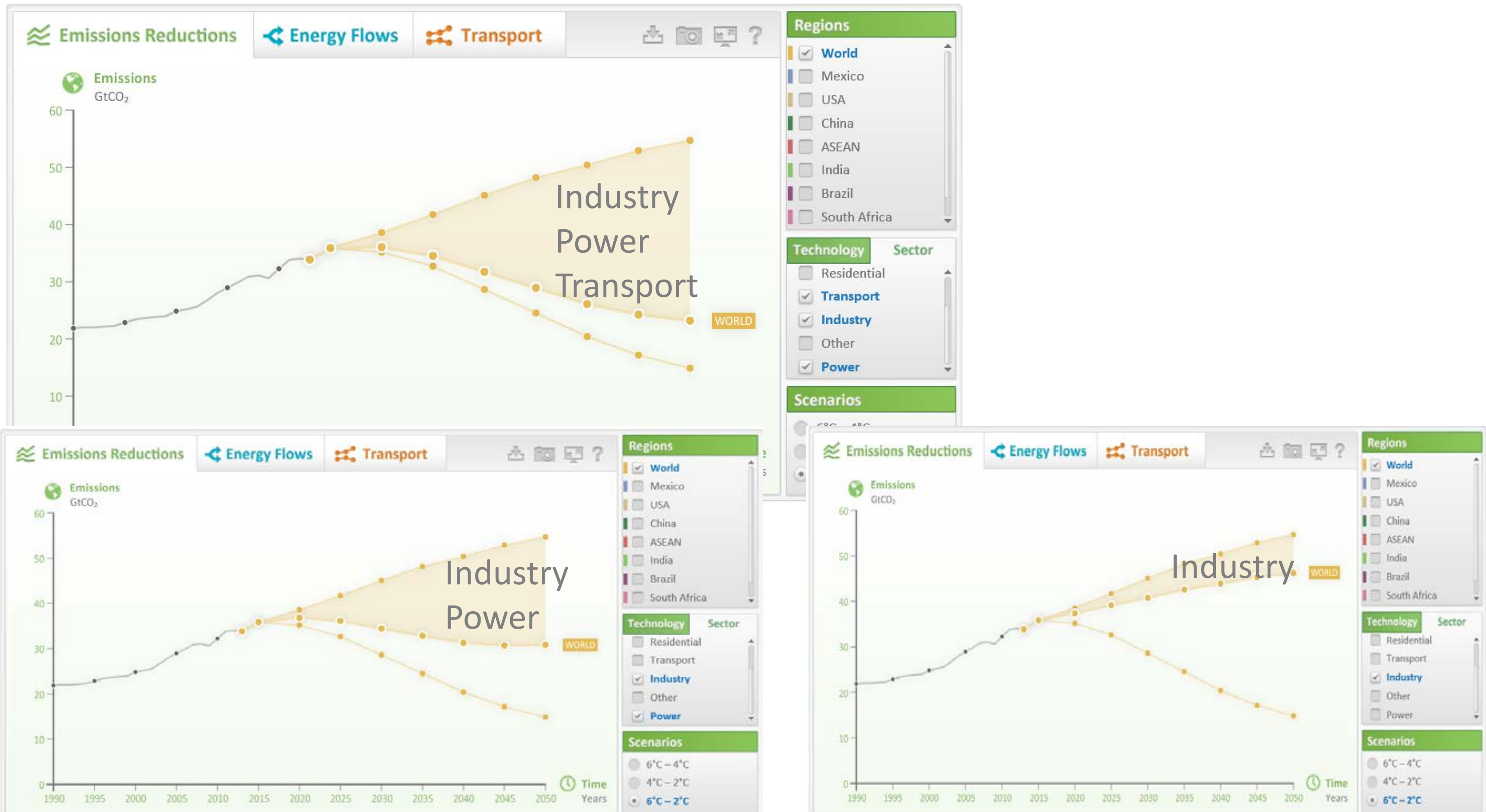
Emissions reductions projected in the 6DS-2DS



Graphs created with ETP 2016 Data Visualization
http://www.iea.org/etp/explore/

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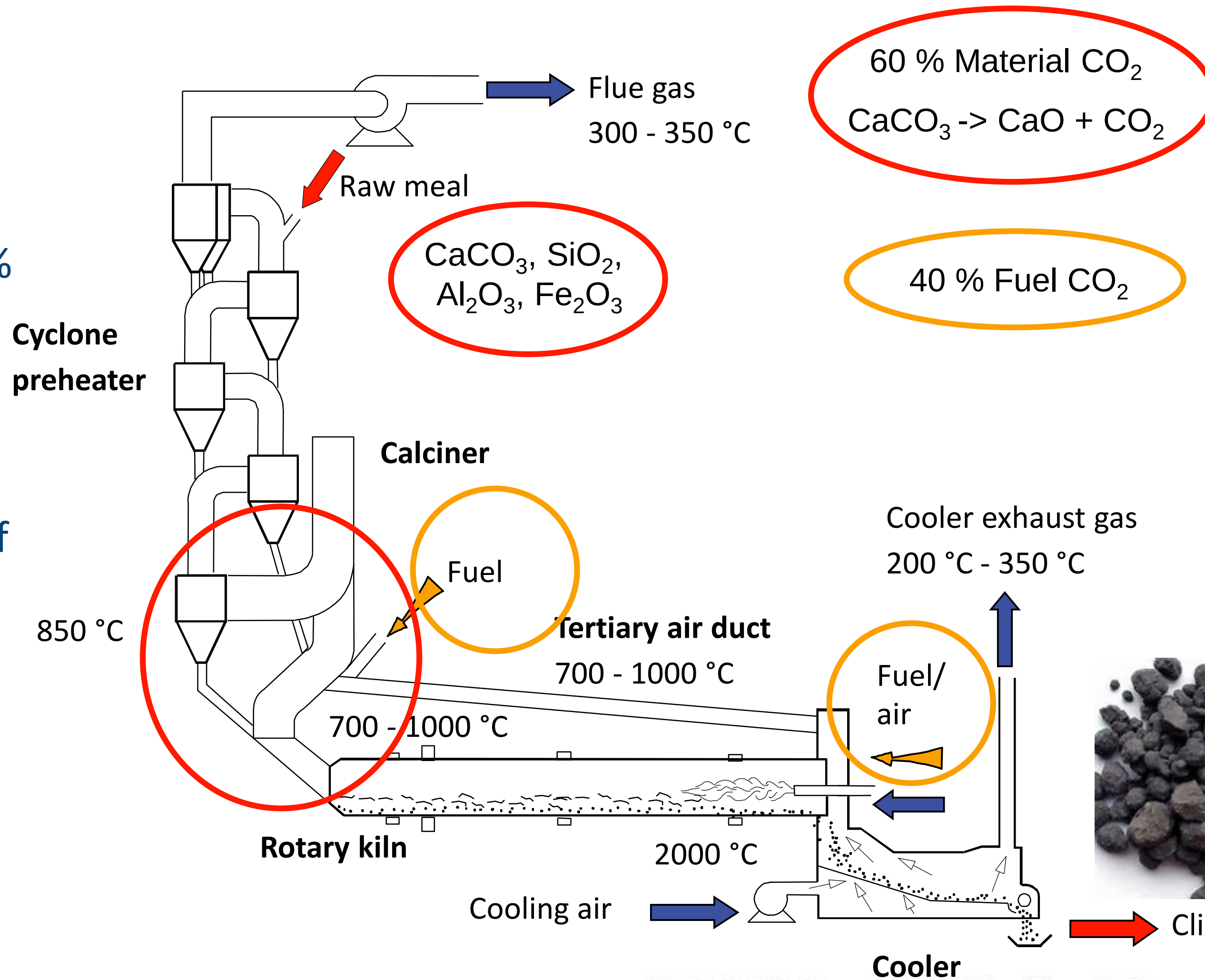
CO_2 emissions from cement production

- Cement production constitute ~5-7% of global anthropogenic CO_2 emissions
- In 2013 ~ 20% of global CO_2 emissions from cement production originated from Europe



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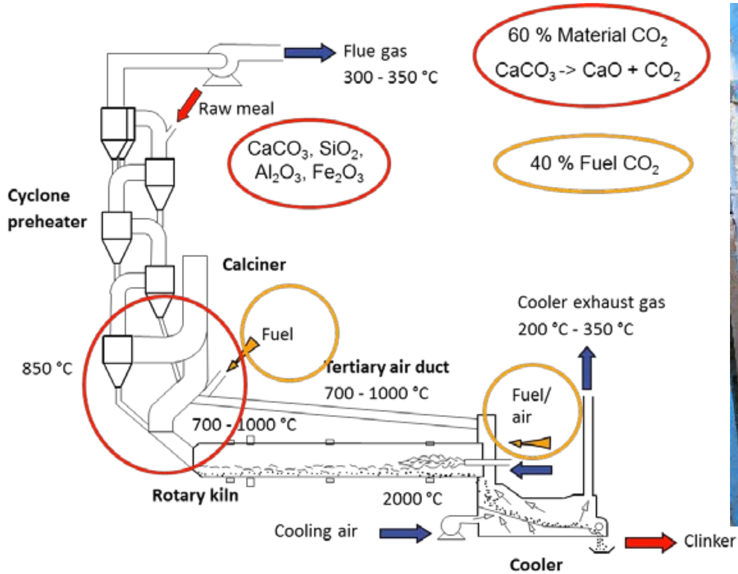
Cyclone preheaters



Calciner fuel feed

Some pictures

from the HeidelbergCement plant in Lixhe, BE

Rotary kiln

Burner

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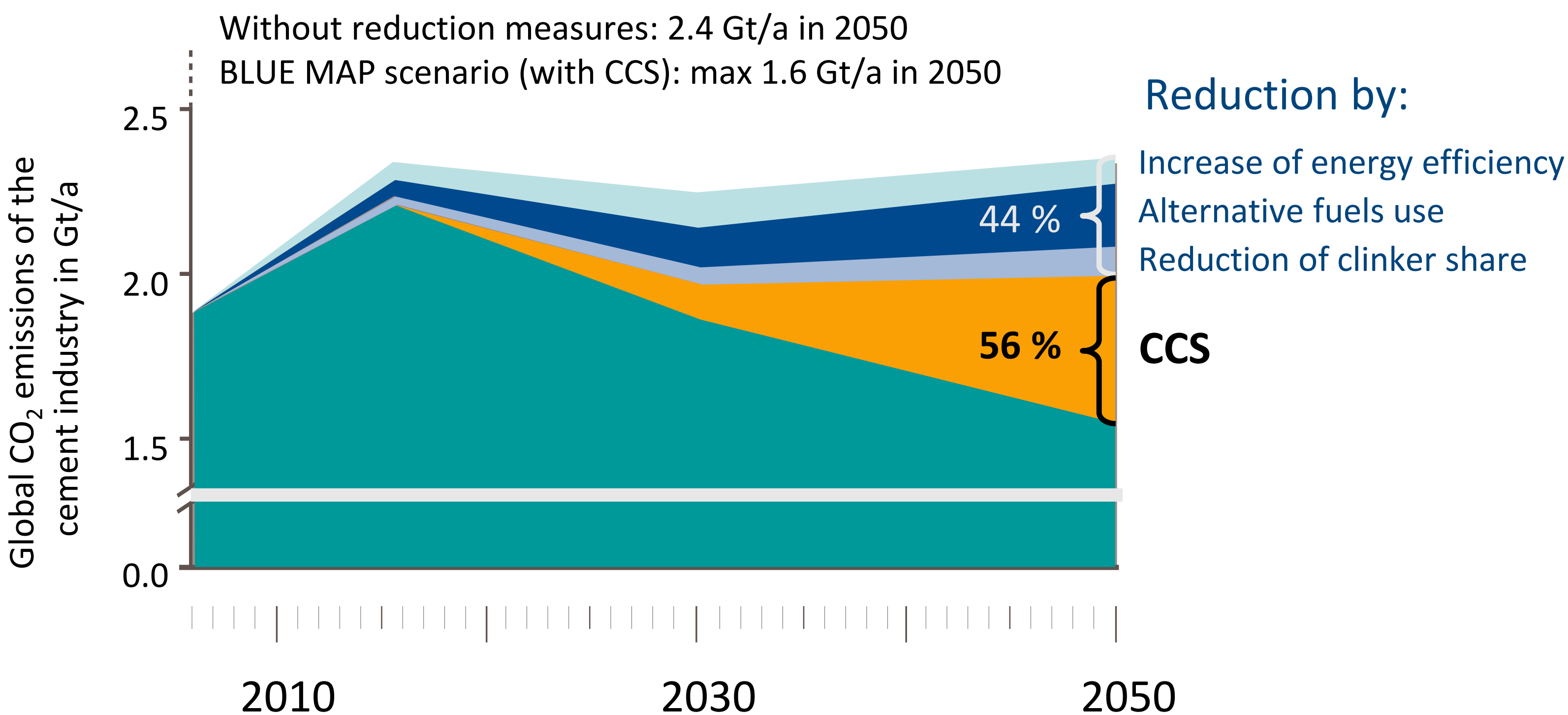
The need for CCS in Cement production



Source: IEA Cement Roadmap

- IEA target for 2050: 50 % of all cement plants in Europe, Northern America, Australia and East Asia apply CCS
- Cement plants typically have a long lifetime (30-50 years or more) and very few (if any) are likely to be built in Europe → **Retrofit**

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The CEMCAP project – CO_2 capture from cement production

The **primary objective of CEMCAP** is to ***prepare the ground for large-scale implementation of CO_2 capture in the European cement industry***

- Project coordinator: SINTEF Energy Research
- Duration: May 1st 2015 – October 31st 2018 (42 months)
- Budget: € 10 million
- EC contribution € 8.8 million
- Swiss government contribution: CHF 0.7 million
- Industrial financing ~€ 0.5 million
- Number of partners: 15

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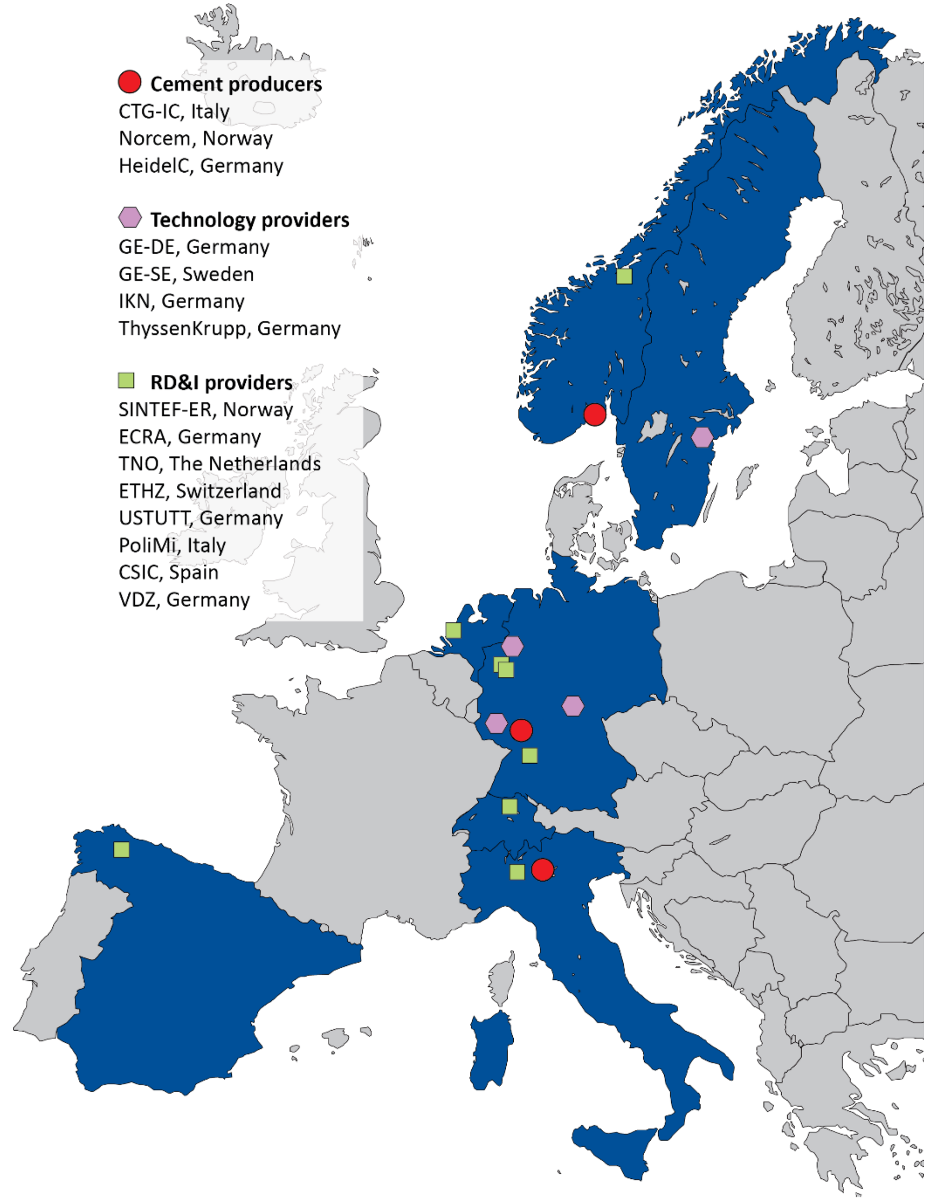
CEMCAP Consortium

<u>Cement Producers</u>
Italcementi, IT
Norcem, NO
HeidelbergCement, DE

<u>Technology Providers</u>
GE Carbon Capture (GE-DE), DE
GE Power Sweden (GE-SE), SE
IKN, DE
ThyssenKrupp Industrial Solutions, DE

<u>Research Partners</u>
SINTEF Energy Research, NO
ECRA (European Cement Research Academy), DE
TNO, NL
EHTZ, CH
University of Stuttgart, DE
Politecnico di Milano, IT
CSIC, ES
VDZ, DE



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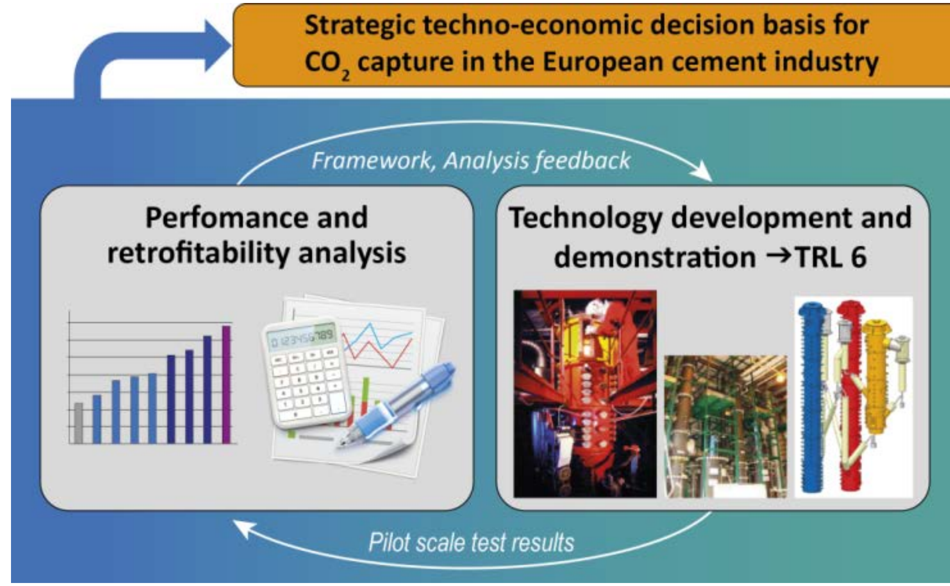

CEMCAP approach: iteration between analytical and experimental research

<u>Analytical work</u>

Framework document

Capture process simulations

Simulations of full cement plants (kilns) with CO_2 capture

Cost estimations/benchmarking

Retrofitability analysis

<u>Experimental work</u>

Testing of three components for oxyfuel capture (linked to ECRA CCS project)

Testing of three different post-combustion capture technologies

~10 different experimental rigs

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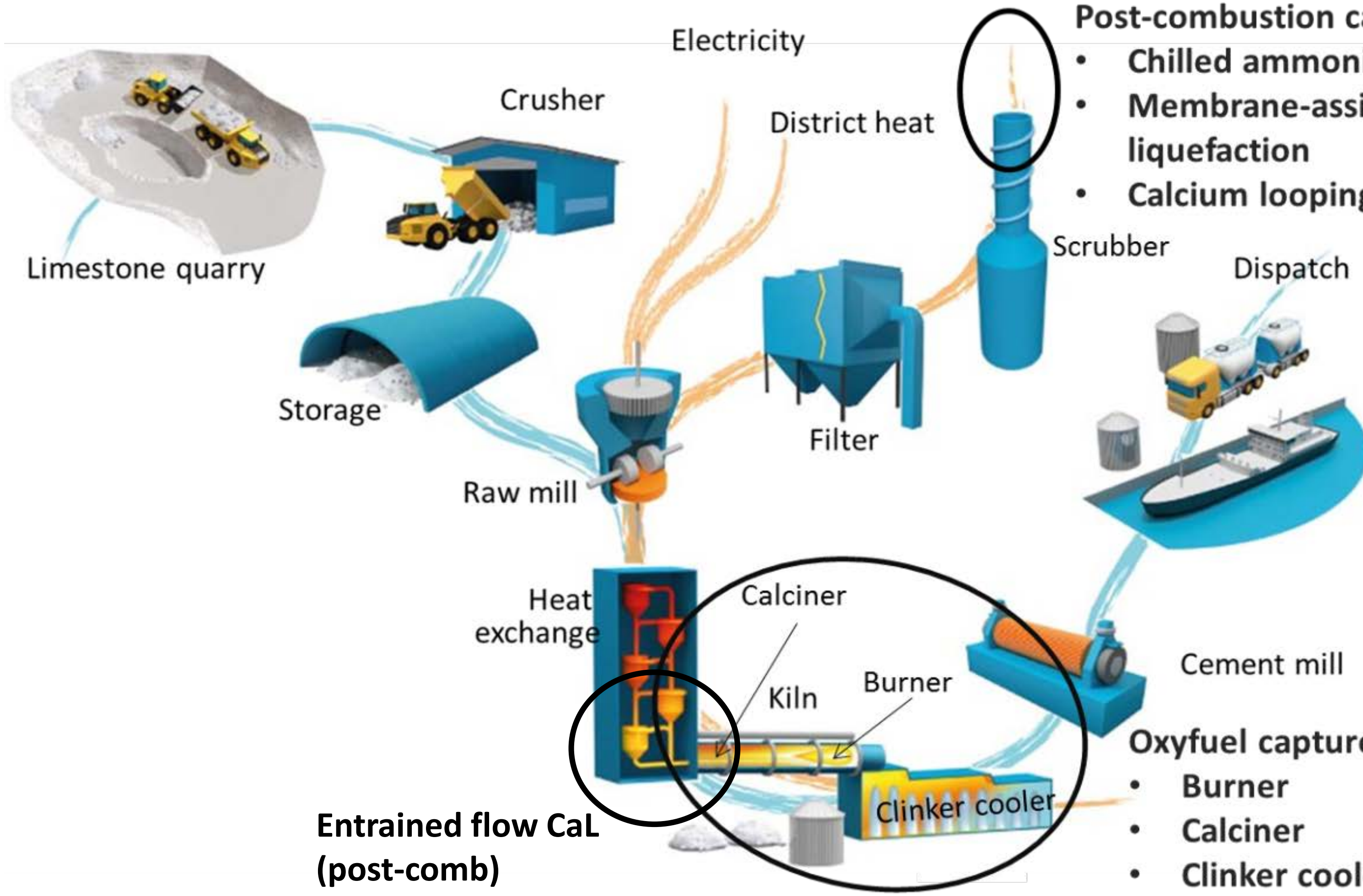
CO_2 capture technology testing in CEMCAP



Post-combustion capture tests:

- **Chilled ammonia (CAP)**
- **Membrane-assisted CO_2 liquefaction**
- **Calcium looping (CaL)**

Oxyfuel capture tests:

- **Burner**
- **Calciner**
- **Clinker cooler**

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End-of-pipe Ca-looping

- Highly suitable for retrofit (carbonator remonves CO_2 from cement plant flue gas)
- CaO-rich purge used as feed to cement kiln but must be cooled and grinded first to reduce particle diameter from d_{50}=100-250μm to d_{50} = 10-20 μm
- CEMCAP case: fuel consumption 8672 MJ_{LHV}/t_{clk}

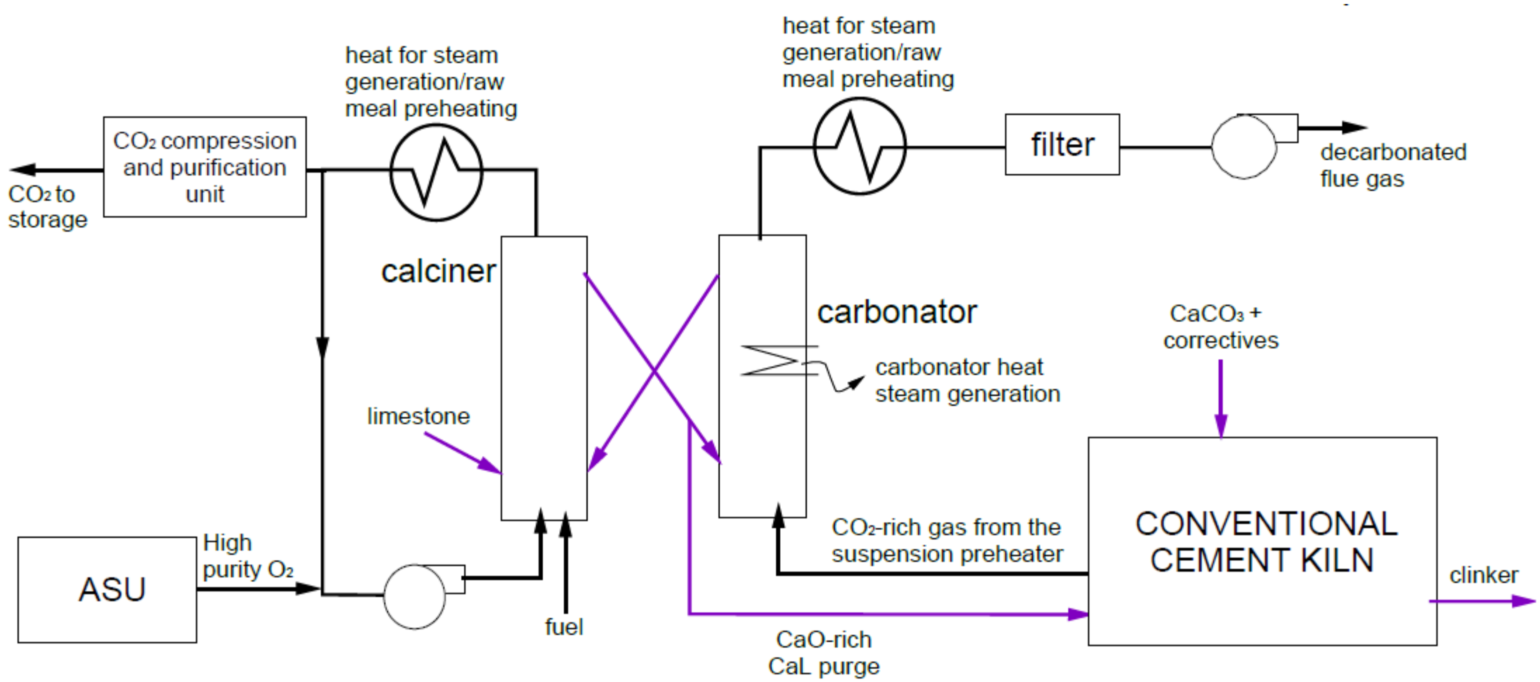

Illustration and results from M.C. Romano et al., "Integration of Ca–Looping systems for CO_2 capture in cement plants" presented at GHGT13, November 14-18, Lausanne, CH

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Integrated Ca-looping

- Carbonator captures CO_2 from rotary kiln, Calciner coincides with cement kiln pre-calciner
- Calcined raw meal used as sorbent in carbonator
- Sorbent particle size: d_{50} = 10-20 μm -> entrained flow reactors
- CEMCAP case: fuel consumption 4748 MJ_{LHV}/t_{clk}

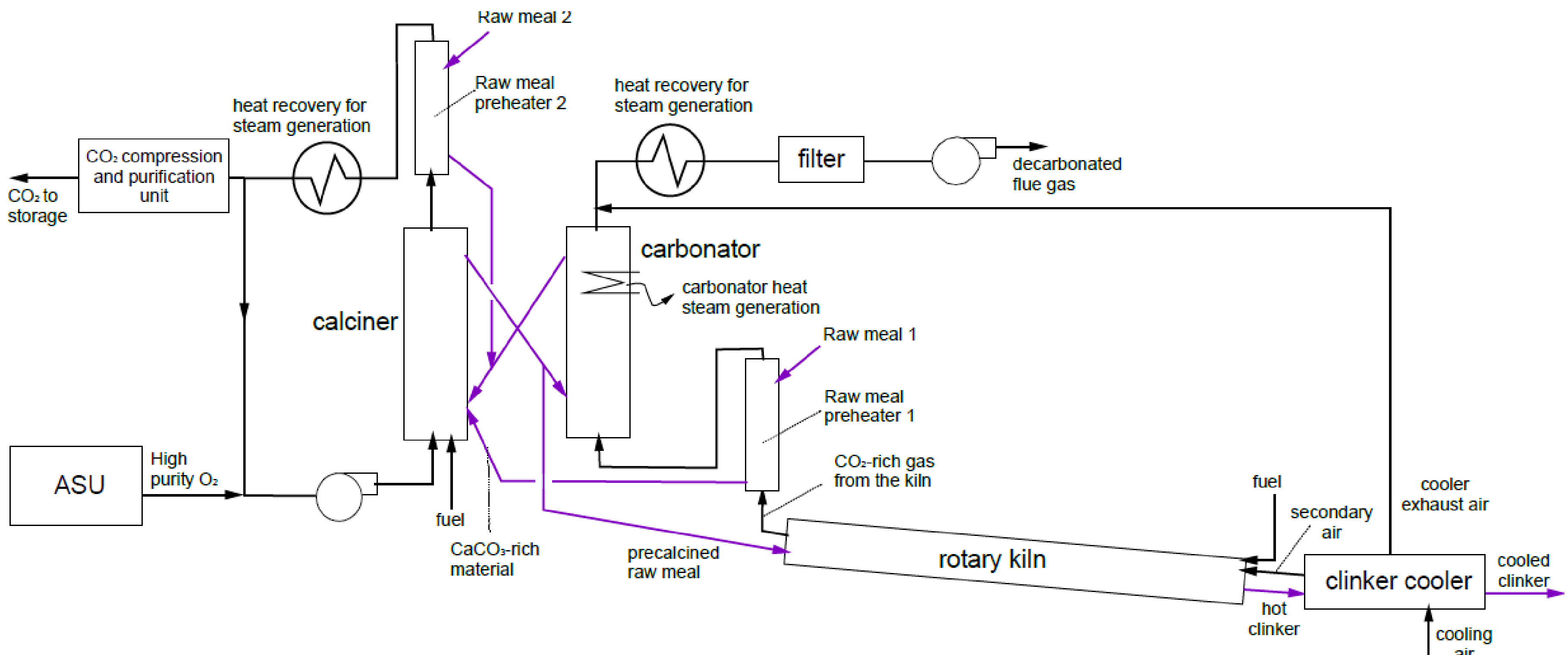

Illustration and results from M.C. Romano et al., "Integration of Ca–Looping systems for CO_2 capture in cement plants" presented at GHGT13, November 14-18, Lausanne, CH

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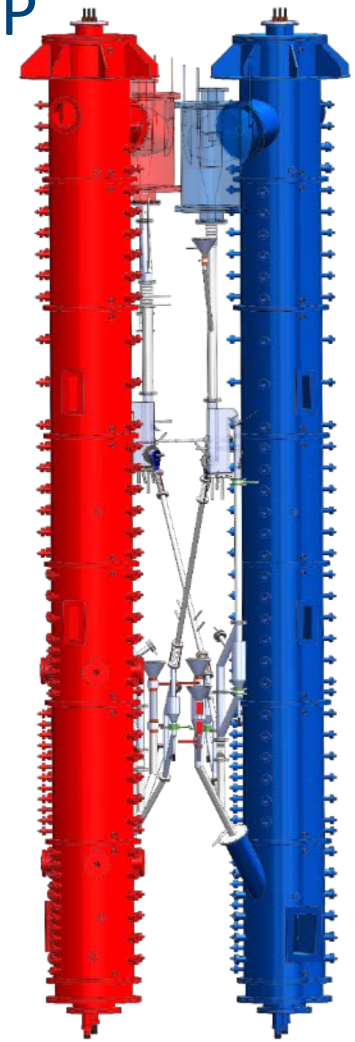
Experimental research on Ca-looping in CEMCAP

- Two rigs adapted to operate under cement plant conditions: 200 kWth pilot rig at IFK, University of Stuttgart and 30 kW rig at CSIC
  - 200 KW rig: Stable calcium looping operation with CO_2 capture rates above 95% has been reached, using high limestone make up flows and a synthetically mixed flue gas.
  - 30 KW rig: experimental campaigns were conducted, investigating the influence of various process parameters upon CO_2 capture rate. Various raw materials for cement production tested and analysed.

CSIC 30 kW rig



IFK 200 kW rig

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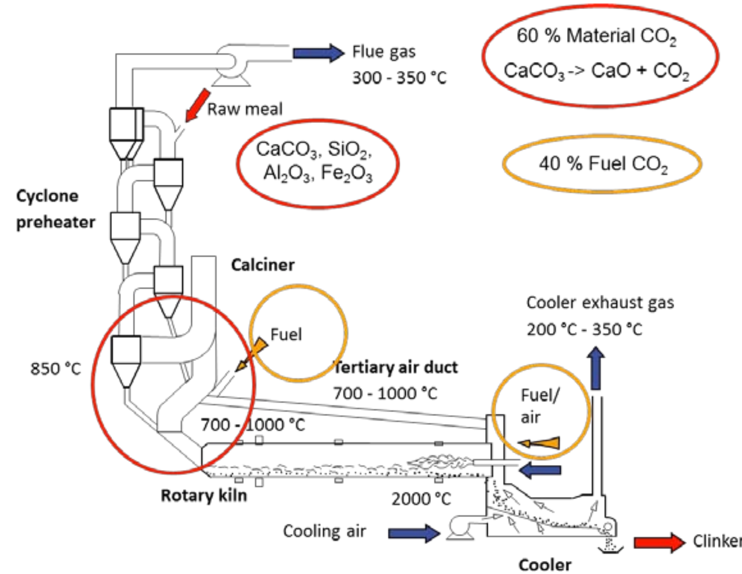

Oxyfuel calcination

- An electrically heated 50 kW entrained flow reactor test facility (IFK, University of Stuttgart) modified for oxyfuel calcination tests, experimental investigation of entrained flow calcination is ongoing.
- Target of investigations: Calcination in CO_2-rich environment
- CEMCAP prototype tests shall show the direct interference of degree of calcination, temperature and residence time for oxyfuel entrained flow calciners.

- Read more about cement plant calciners and the in CEMCAP deliverable ***D8.1: Status Report on Calciner Technology*** available on the CEMCAP website

Oxyfuel clinker cooler

- Oxyfuel cement plant -> clinker must be cooled in a CO_2-rich environment
- Maintained clinker quality must be confirmed
- An oxyfuel clinker cooler prototype (constructed by IKN) has been installed at the HeidelbergCement plant in Hannover
- Tests are ongoing

Clinker extraction device being mounted

Installation of clinker cooler

Hot commissioning

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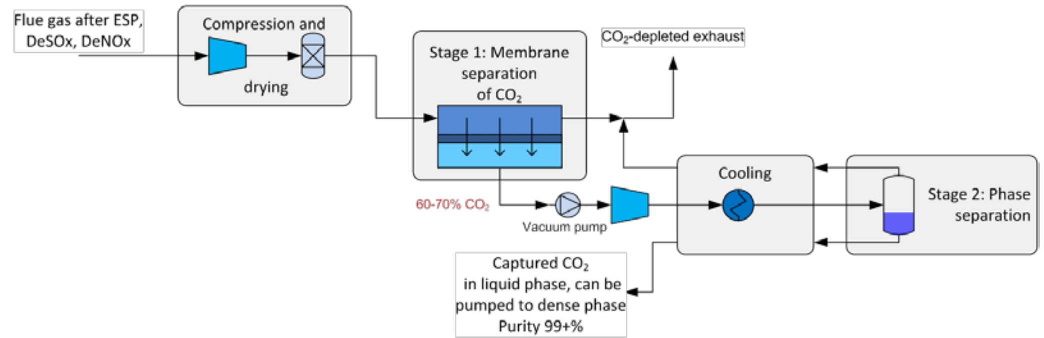
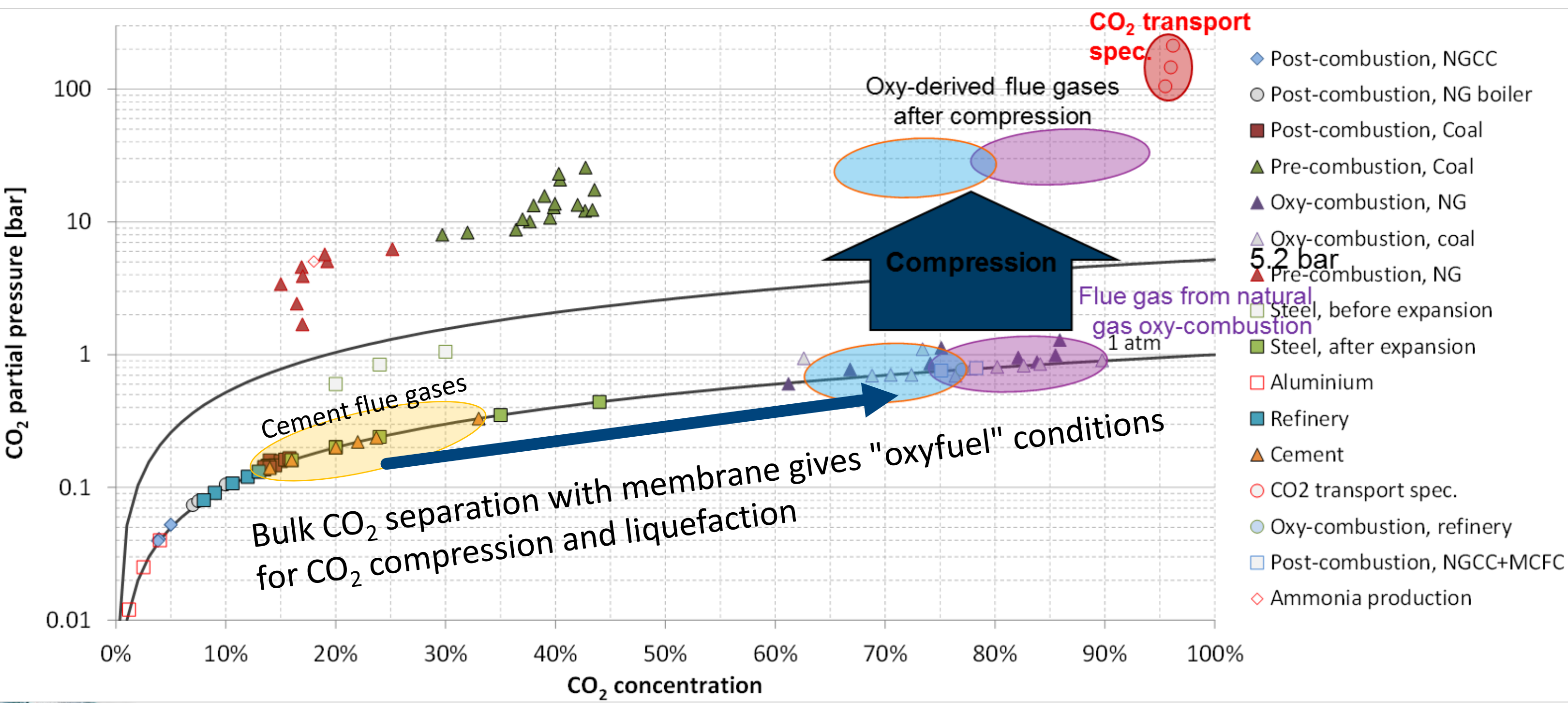
Post combustion capture from cement: Membrane-assisted CO_2 liquefaction

- End-of-pipe technology (requires De-SOx, De-NOx, dehydration)
- No fuel input, only power





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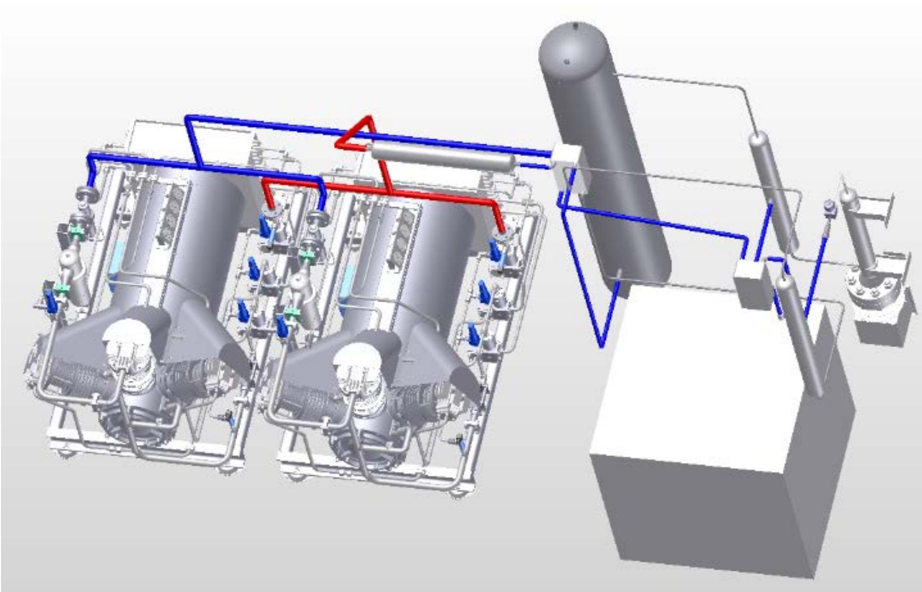
Operating conditions for CO_2 capture ratio and CO_2 purity to be tested in a 10-ton$_{CO2}$-per-day lab pilot rig at SINTEF



Chilled ammonia process (CAP) for cement plants

- An existing CAP pilot plant (1 tonne CO_2/day) at GE Power Sweden has been adapted for CEMCAP conditions (up til 34% CO_2 concentration)
- Absorber, Direct Contact Cooler and water wash sections to be tested

CAP pilot plant used for CEMCAP tests (photo by GE Power Sweden)

Characteristics of technologies included in CEMCAP

	Oxyfuel capture	Post combustion capture technologies		
		Chilled ammonia	Membrane-assisted CO_2 liquefaction	Calcium Looping
CO_2 capture principle	Combustion in oxygen (not air) gives a CO_2-rich exhaust	NH_3/water mixture used as liquid solvent, regenerated through heat addition	Polymeric membrane for exhaust CO_2 enrichment followed by CO_2 liquefaction	CaO reacts with CO_2 to from $CaCO_3$, which is regenerated through heat addition
Cement plant integration	Retrofit possible through modification of burner and clinker cooler	Retrofit appears simple, minor modifications required for heat integration	No cement plant modifications. Upstream SOx, NOx, H_2O removal required	Waste from capture process (CaO) is cement plant raw material
Clinker quality	Maintained quality must be confirmed	Unchanged	Unchanged	Clinker quality is very likely to be maintained
CO_2 purity and capture rate	CO_2 purification unit (CPU) needed. High capture rate and CO_2 purity possible (trade-off against power consumption).	Very high CO_2 purity, can also capture NOx, SOx. High capture rate possible.	High CO_2 purity (minor CO_2 impurities present). Trade-off between power consumption and CO_2 purity and capture rate.	Rather high CO_2 purity (minor/moderate CO_2 impurities present). High capture rate.
Energy integration	Fuel demand unchanged. Waste heat recovery + electric power increase.	Auxiliary boiler required + waste heat recovery. Electricity for chilling.	Increase in electric power consumption, no heat integration.	Additional fuel required, enables low-emission electricity generation.

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CEMCAP results

- Available on website:
  - ***D4.1: Design and performance of CEMCAP cement plant without CO_2 capture***
  - ***D4.2 Design and performance of CEMCAP cement plant with MEA post combustion capture***
  - ***D8.1: Status Report on Calciner Technology***
  - ***D12.1 Results from 30 kW_{th} CaL CFB experiments***

- Some of the reports coming later in 2017:
  - The CEMCAP framework
  - Results from entrained flow CaL tests

- Reports, presentations et.c. on http://www.sintef.no/projectweb/cemcap/results/

Thank you for your attention!

Questions?

Acknowledgement

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www.sintef.no/cemcap

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Newsletter subscriptions, inquiries: cemcap@sintef.no

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