Process characteristics of clinker and cement production

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CLUSTER Meeting, Hamburg, 26.10.2017

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Cement production and concrete as building material

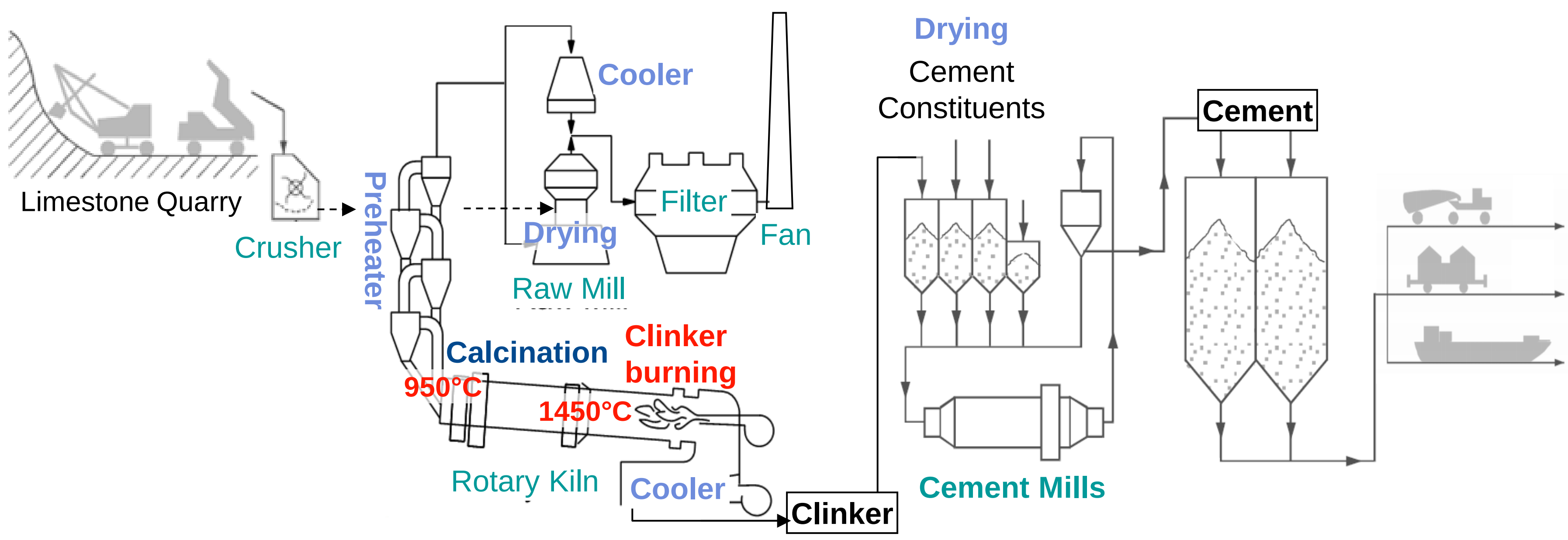
Cement plant with rotary kiln, preheater tower and raw material grinding

The properties of concrete make it a primary building material where reliability and durability are required.

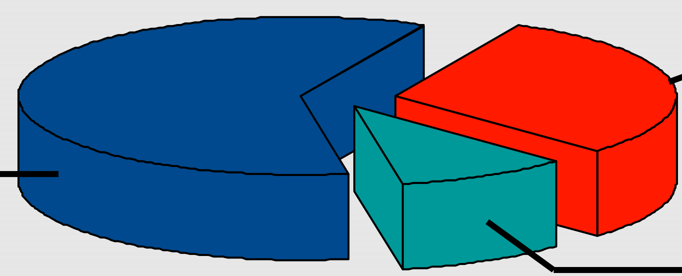
Depending on the application ~ 300 kg cement are used for 1 m^3 of concrete.

The cement industry emits ~ 7% of global anthropogenic CO_2 emissions. China >50%.

Cement production process: Thermal energy demand and CO_2 emissions



process emissions from calcination of limestone 60%



30% fuel emissions thermal energy prod.

10% electric power consumption, indirect emissions

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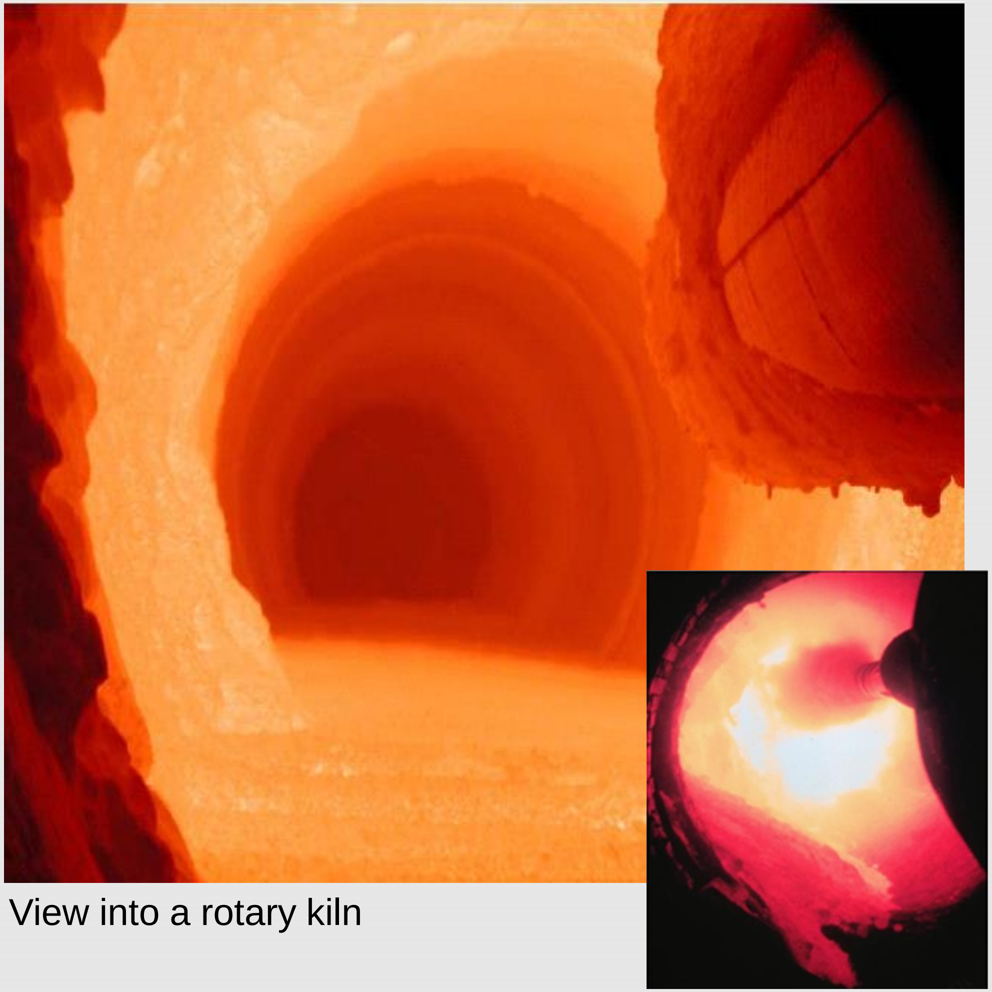
Continuous high temperature process in the cement industry: Calcination and cement clinker burning



View into a rotary kiln

Calcination of raw material

$CaCO_3 \Rightarrow CaO + CO_2$

- Process emissions of raw material:
  = 0.54 t CO_2/t clinker
- Endotherm reaction at 950 °C
  ca. 1700 MJ/t clinker
  ≈ 50% of energy

Cement clinker burning at 1450 °C

- formation of hydraulic properties of clinker

Thermal energy requirement:

ca. 3510 MJ/t clinker
(CSI GNR-2014)

Electrical energy requirement:

ca. 110 kWh/t cement (VDZ)

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CLUSTER Meeting, Hamburg, 26 October 2017

CEMCAP – first experimental results and conclusions

Johannes Ruppert
VDZ gGmbH - Research Institute of the Cement industry

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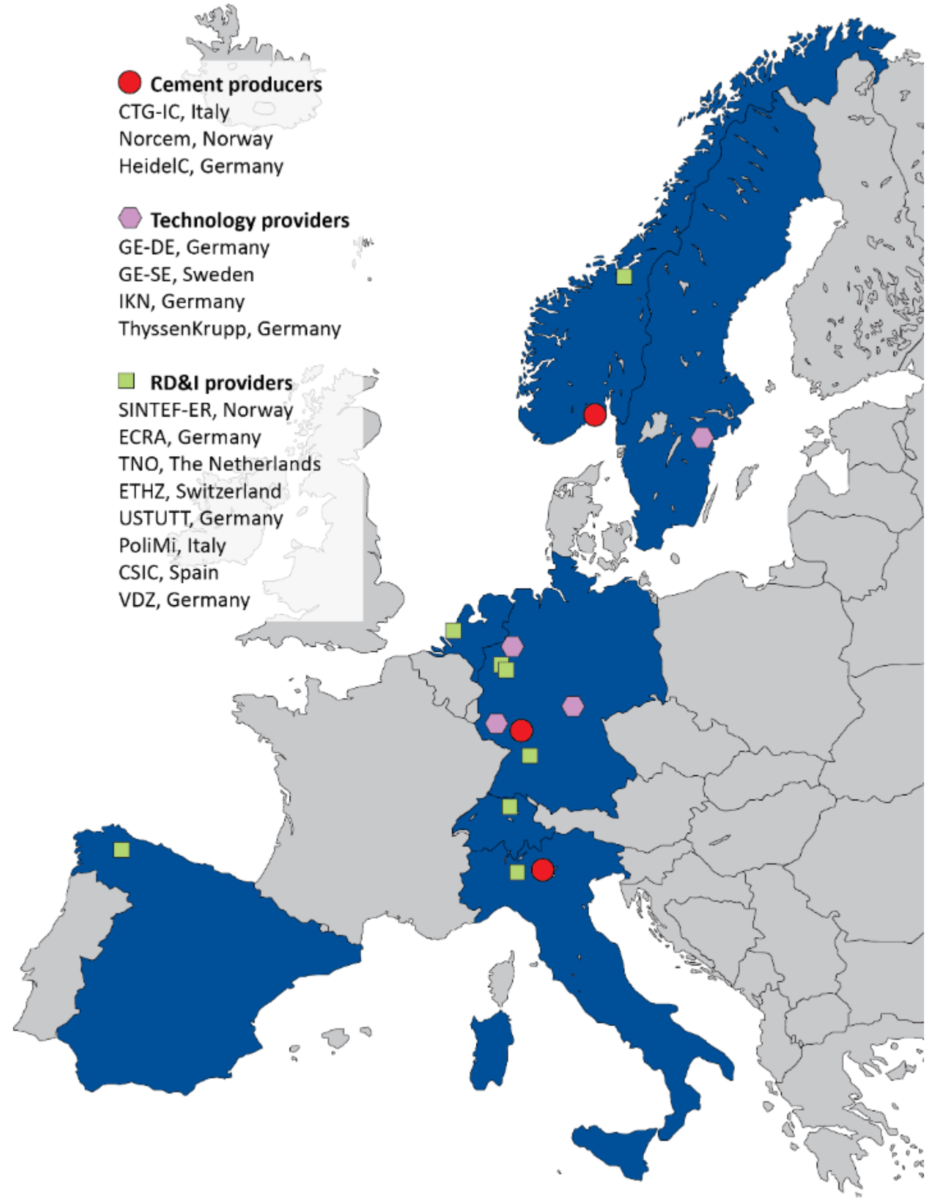
CEMCAP Consortium

<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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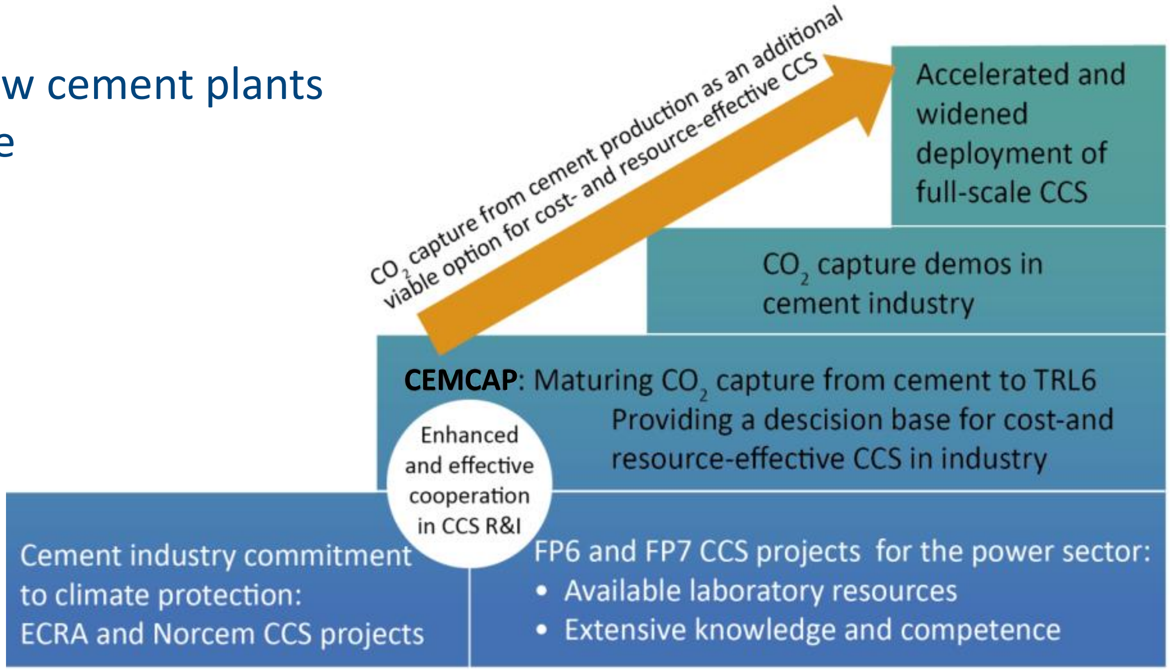
CEMCAP ambition

- CEMCAP will deliver strategic conclusions for how to progress CO_2 capture from cement plants from pilot-scale testing to demonstration
- Recommendations will be given for different scenarios (i.e. different types of cement plants at different locations in Europe)
- Focus is on **retrofit** – very few new cement plants are foreseen to be built in Europe

- CEMCAP oxyfuel results will be directly exploited in the ECRA CCS project
- Ca-looping results in H2020 CLEANKER project
- Exchanges with LILAC project: Direct separation technology



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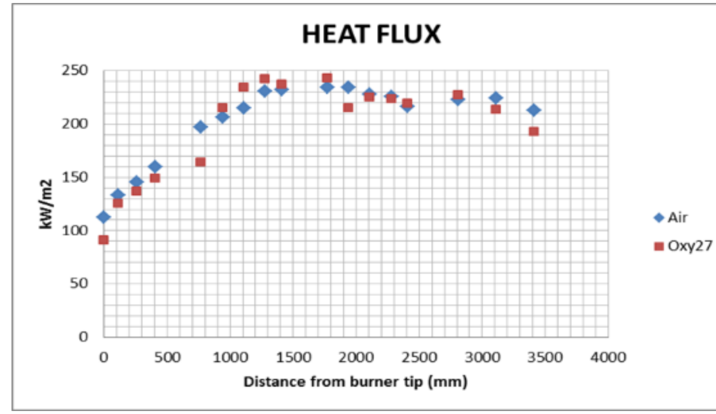
Experimental CEMCAP research

Oxyfuel capture

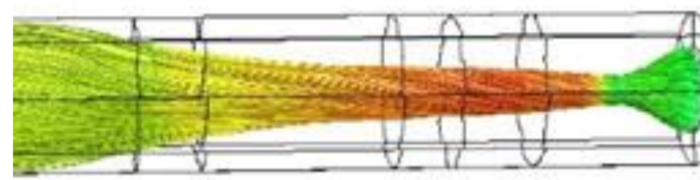
Oxyfuel cement burner tests

Oxyfuel burner design by ThyssenKrupp for cement plant operating conditions

Oxyfuel burner testing at IFK, University of Stuttgart



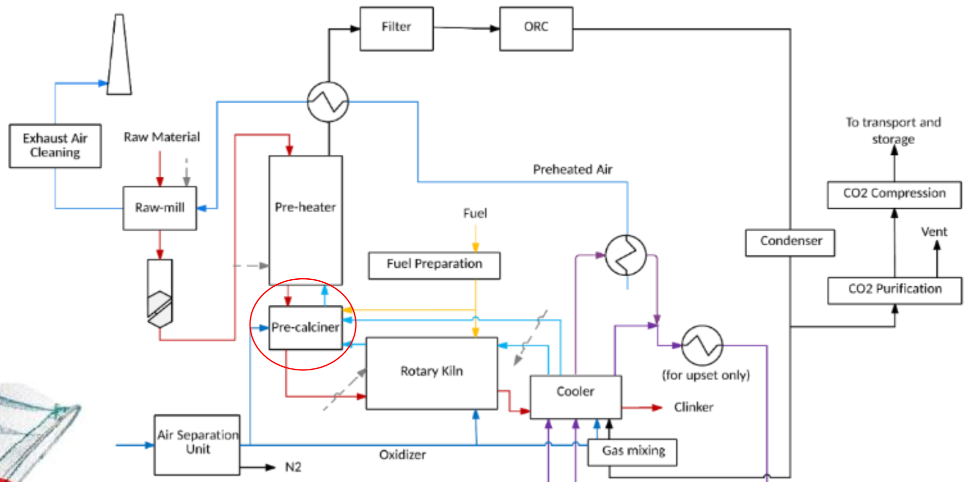
Measurements of incident total heat flux to the furnace wall during second test campaign.

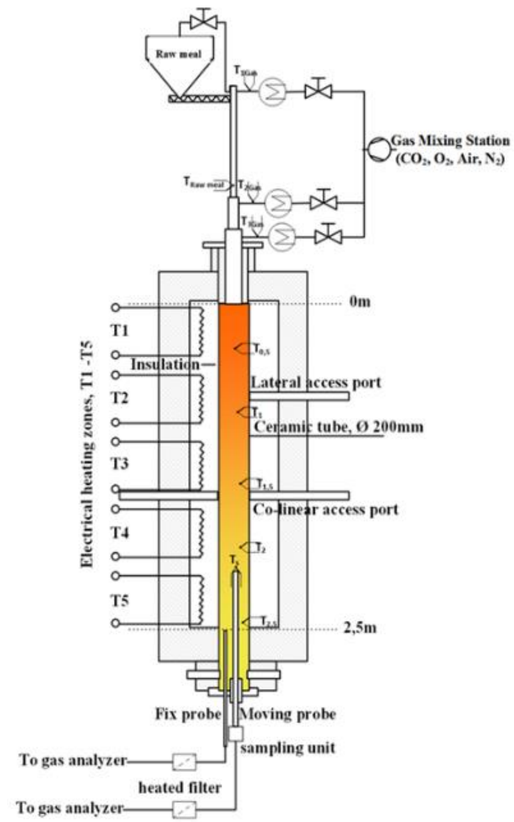


Result from the SINTEF CFD simulation of the oxy-fuel case tested in the second campaign showing streamlines coloured by temperature.

Calciner technology for oxyfuel capture

- Purpose is experimental investigation of suspension calcination under industrially relevant oxy-fuel conditions
- Aim is to verify sufficient calcination of the raw material before its entering into the rotary kiln
- Experimental work is concluded, final analysis ongoing





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Oxyfuel clinker cooler – designed, built, tested

Clinker cooler prototype and recirculation system installation at HeidelbergCement in Hannover

Hot commissioning of the oxyfuel clinker cooler and first oxyfuel clinker samples

Clinker analysis is ongoing

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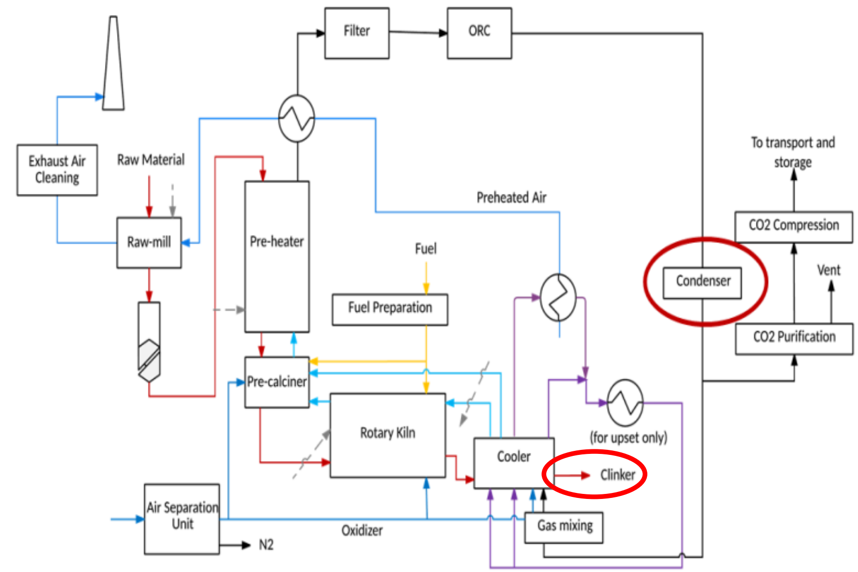
WP 9 – Experimental results

- Considerably high false air ingress through the cold clinker discharge system outlet.
- No leakages of CO_2–rich gas occurred during the trials.
- Cooling gas recirculation contributed to a phenomenon of moisture enrichment.
- The clinker microstructure of the clinker samples indicate fast cooling .
- Cooling rate was enhanced by the extraction of finer clinker granules from the kiln and high false air ingress.

WP 9 – Relevant findings for the industry

WP9 researchers concluded that…

- … if high water contents in the cooling medium prove to affect product quality, special attention shall be given to the **design of the condenser**, whose installation in future oxyfuel cement plants has been already envisaged by ECRA.
- … **cold clinker discharge system** shall get special attention regarding minimisation of false air in-leakage in industrial scale projects.



- … **equipment sealing** proved to be effective at pilot scale. The use of similar sealing technology in industrial scale shall be regarded with caution:

  1) operation conditions are more severe in industrial scale.

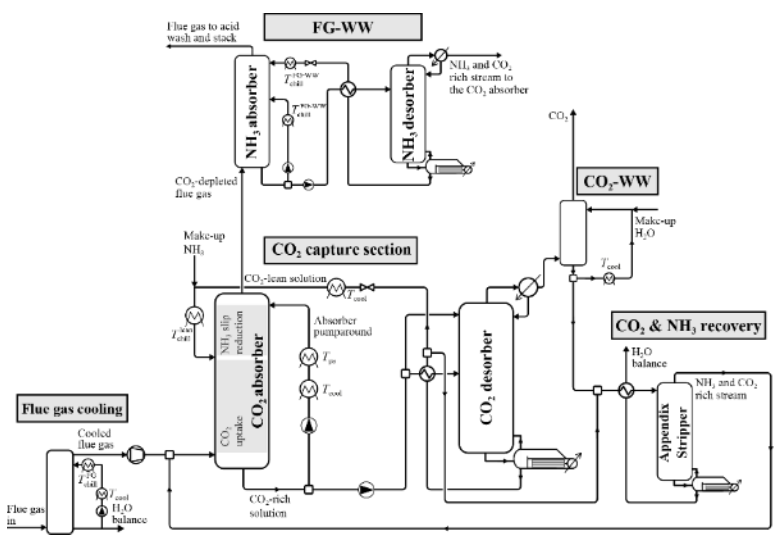
  2) sealing's durability and efficiency over time were not assessed during the experiment.

Experimental CEMCAP research

Post combustion capture

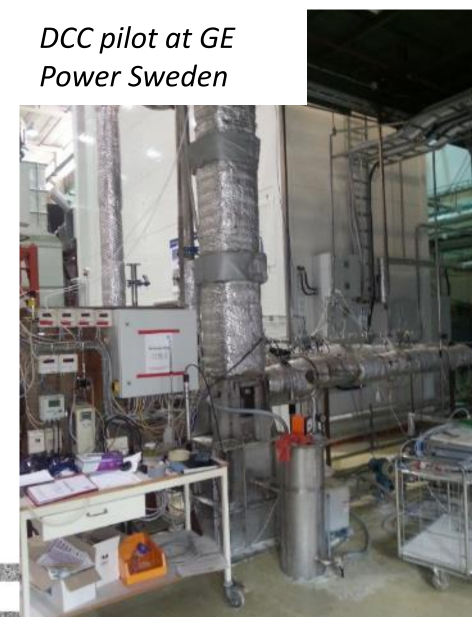
Chilled ammonia for cement plant CO_2 capture

- ETHZ has simulated and adapted the CAP system to different cement-plant flue gases;
- New rate-based model was developed and used to validate full-scale CAP simulations for cement plants. Upcoming work: CAP optimization
- The Absorber and Direct Contact Cooler (DCC) units were tested under cement-like conditions at GE Power Sweden, Water wash section will be tested later in 2017



CAP process flowsheet

DCC pilot at GE Power Sweden



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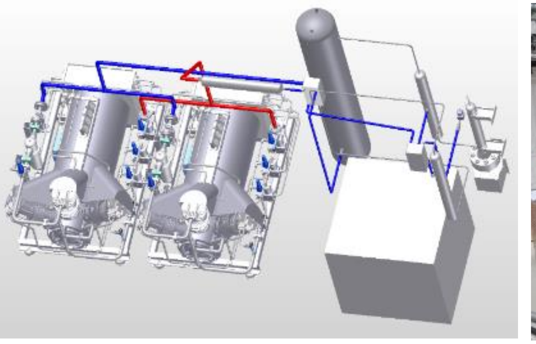
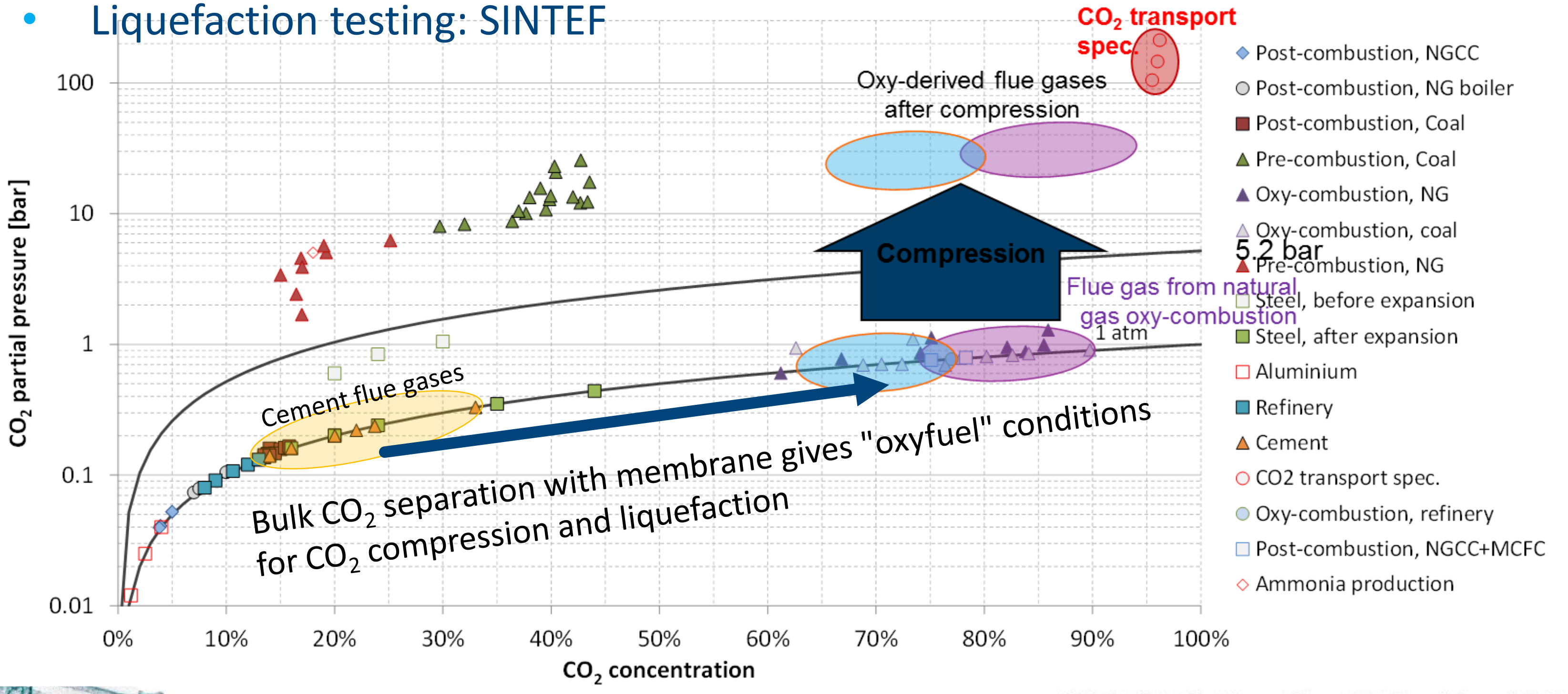
Membrane-assisted CO_2 liquefaction

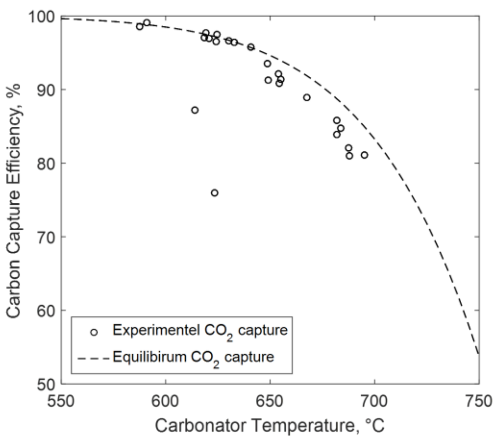
- End-of-pipe technology (requires De-SOx, De-NOx, dehydration)
- No fuel input, only power
- Membrane testing: TNO
- Liquefaction testing: SINTEF





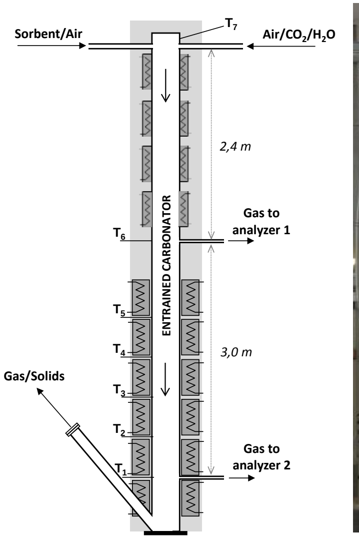
Calcium looping for cement plants

- Tail-end CO_2 capture: tests at 200 kW Ca-looping CFB test facility at IFK/Stuttgart University



Experimental results on CaL CO_2 capture efficency versus equilibirum CO_2 capture (IFK/USTUTT)

- Entrained-flow (integrated) Ca-looping: tests at CSIC



Experimental setup at CSIC

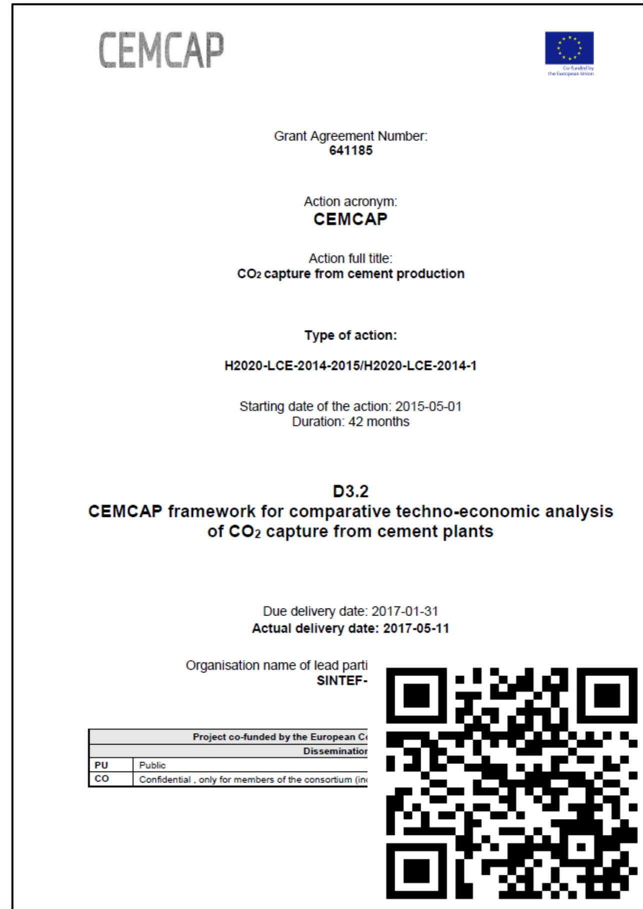
- Process simulations/sizing of full-scale Ca-looping conducted alongside exp work (Politecnico di Milano)
- "Spin-off project" H2020 CLEANKER

Analytical CEMCAP research

CEMCAP framework document: ready for use!

- For consistent comparative assessment of capture technologies for cement plants
- Provides information relevant for experimental and simulation work

- Defines:
  - A reference cement clinker production line
  - Specs for standard process units
  - Utilities description, cost and climate impact
  - Extent of capture and CO_2 specs
  - Economic parameters
  - Key performance parameters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Grant Agreement Number:
641185

Action acronym:
CEMCAP

Action full title:
CO_2 capture from cement production

Type of action:

H2020-LCE-2014-2015/H2020-LCE-2014-1

Starting date of the action: 2015-05-01
Duration: 42 months

D3.2
CEMCAP framework for comparative techno-economic analysis of CO_2 capture from cement plants

Due delivery date: 2017-01-31
Actual delivery date: 2017-05-11

Organisation name of lead parti
SINTEF-

Project co-funded by the European C	
	Disseminatior
PU	Public
CO	Confidential , only for members of the consortium (in

Download from
www.sintef.no/cemcap/results

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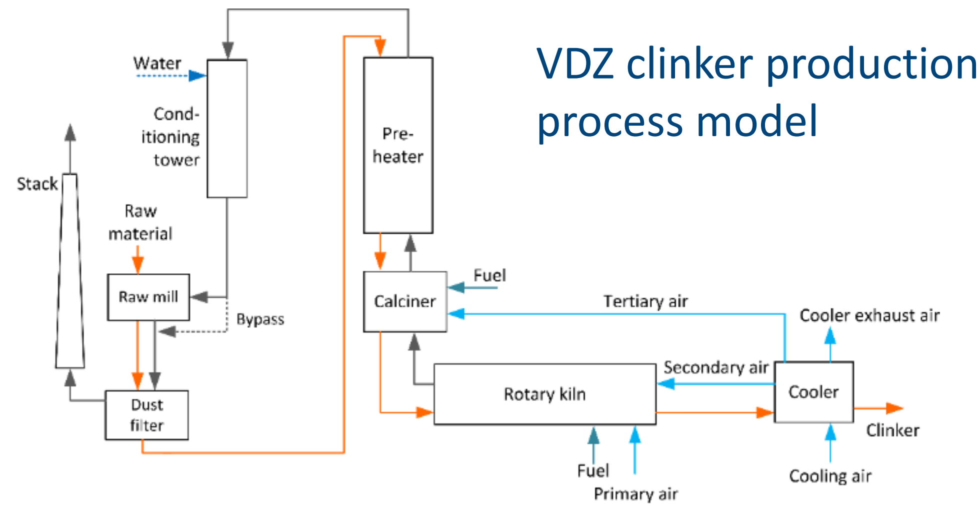
Comparative capture process analysis (benchmarking)

- Concluded and avaialble on the CEMCAP website:
  - A BAT reference cement plant report, relying on the CEMCAP framework
  - A cement plant reference case with MEA (also poster/paper at GHGT13)



VDZ clinker production process model

- Work in progress, not published:
  - Process simulations with comparsion of CO_2 capture
  - Costing methodology

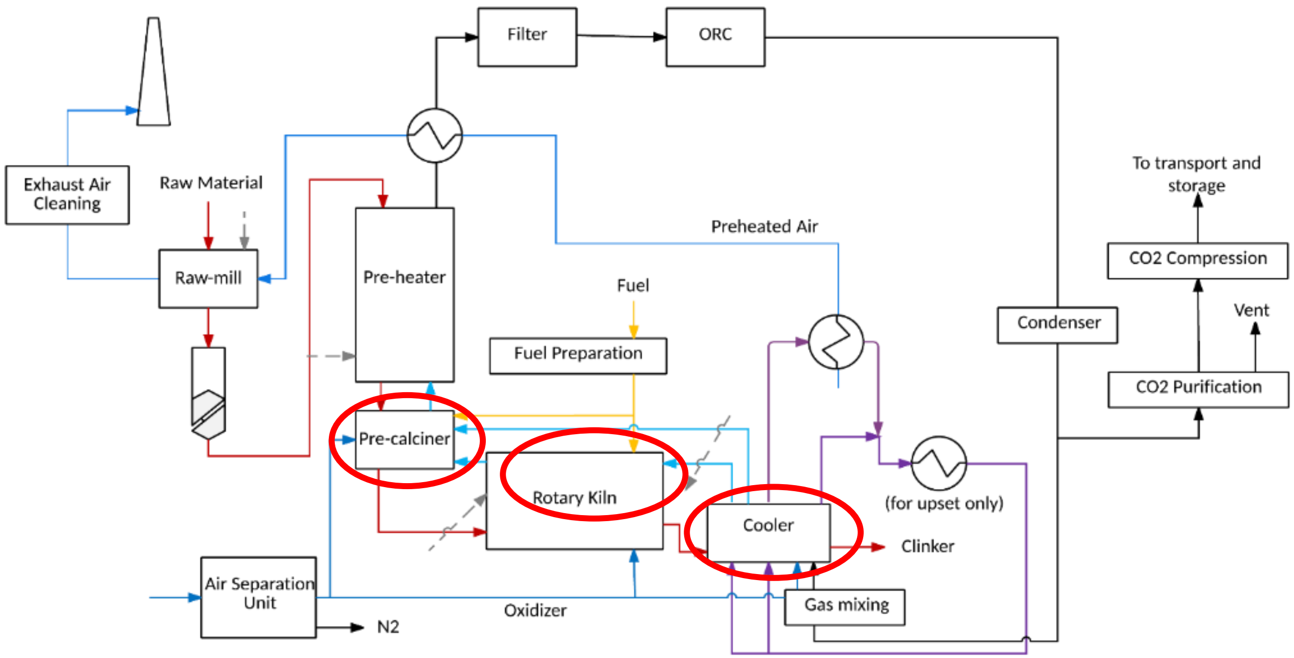
- Remaining work:
  - Final process simulations of all capture technologies
  - Retrofitability study
  - Final techno-economic comparison

Process analysis example: Oxyfuel modelling

Purpose: Optimization of the oxyfuel clinker burning process based on process modeling verified by prototype results

Oxyfuel principle: Air is replaced by recirculated CO_2 in the plant, to enable capture of highly concentrated CO_2

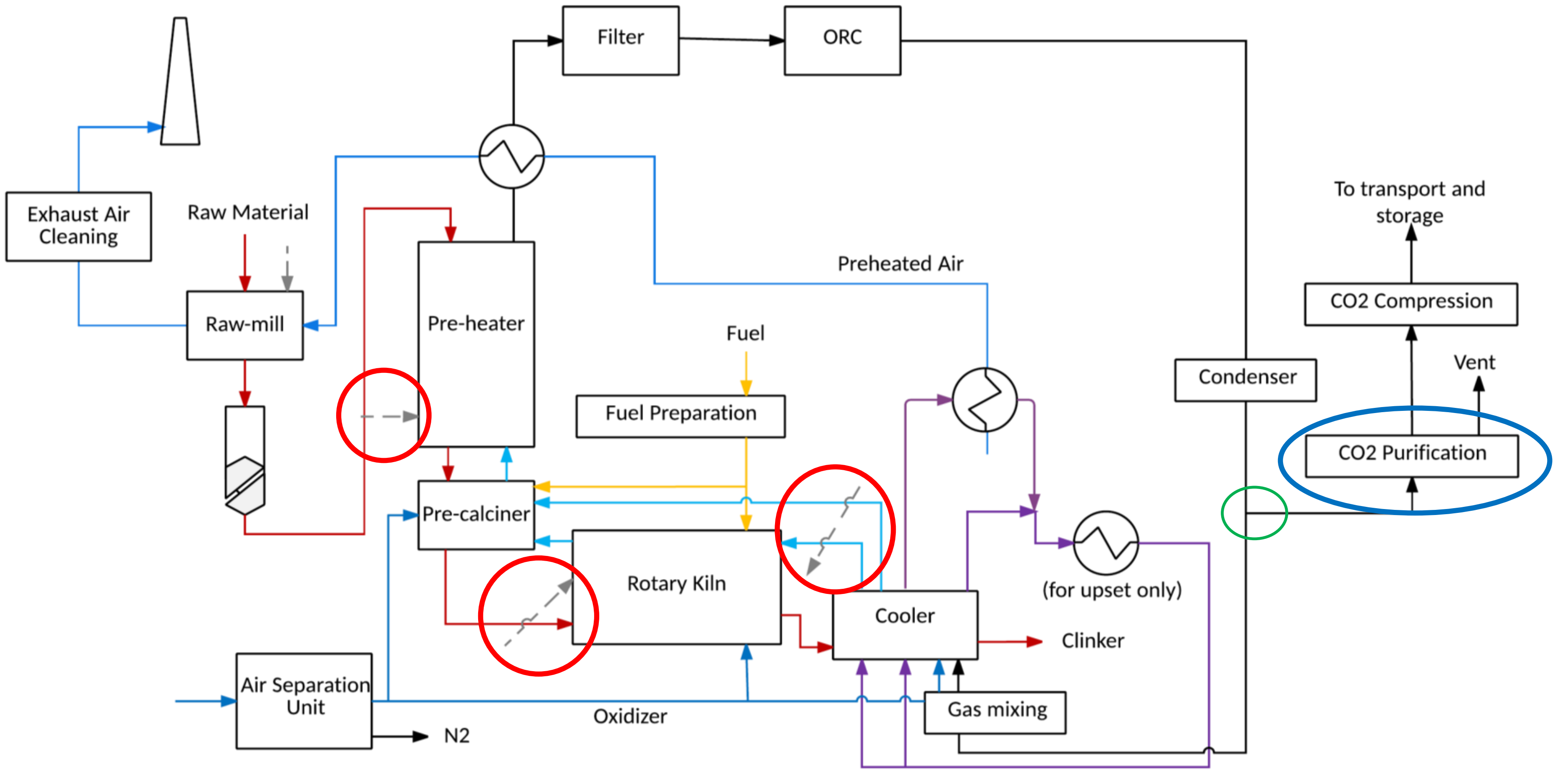
Oxyfuel research in CEMCAP is closely connected to the ECRA CCS project



1. Pre-calciner,
2. burner and
3. clinker cooler

tested in CEMCAP

Oxyfuel modelling: CPU electrical energy demand depending on air in leakage



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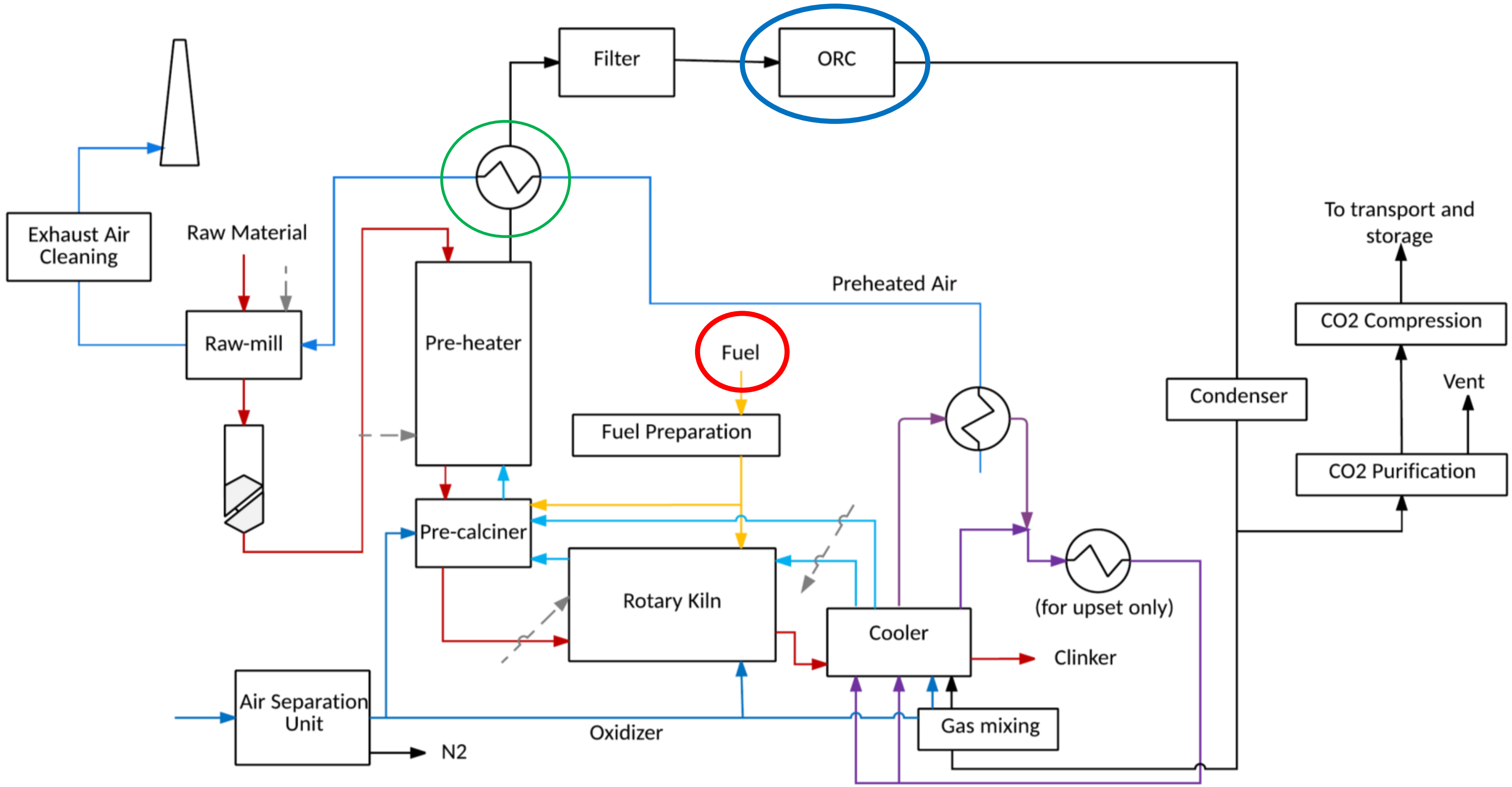
Possibilities for power generation by fuel feed variation



Modelling results and relevant findings for the industry

Effect of false air ingress variation: +4% false air = +13% CPU power demand

Fals air ingress	4%	6%	8%
Feed purity (dry), mol%	88.2	84.3	80.7
CO_2 product purity, mol%	97.6	97.5	97.2
CO_2 capture ratio, %	90	90	90
CPU power, kWh/t CO_2	167	173	189

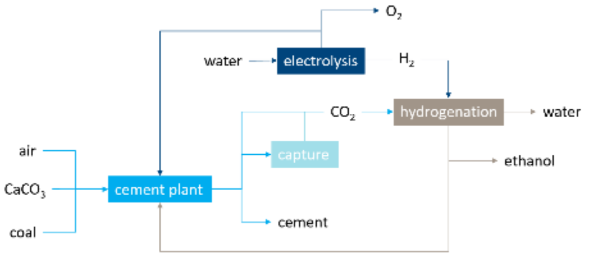
Effect of increased fuel input for Waste Heat Recovery (WHR)

- Fuel feed variation
  - Increase in fuel thermal energy input of 2150 kW
  - The electricity output from the ORC increased by 450 kW
  - This represents an high ORC efficiency of 21 %, however lower than power plants

Post capture CO_2 management

(what to do with the captured CO_2 if you are in the cement industry?)

- Cement-production post-capture CO_2 management routes investigated in CEMCAP:
  1. CCS: Geological sequestration: option to be defined (TNO)
  2. CCS: Mineralization to $MgCO_3$ (ETH Zurich)
  3. CCU: CO_2 hydrogenation to ethanol (TNO)
  4. CCU: CO_2 polymerization to Poly(propylene carbonate) (TNO)
  5. CCU: food-grade CO_2 (TNO)



- Product fact sheets for different CCU routes are being prepared and will be published in October

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Oxyfuel experimental workpackages are concluding their work in 2017

- Oxyfuel clinker cooler experiment in HeidelbergCement plant Hannover until 3/2017
- Oxyfuel calciner and burner experiments at University of Stuttgart: 8/2017, 12/2017

Carbon Capture Technologies in the Cement Industry

2^{nd} ECRA/CEMCAP Workshop, Düsseldorf, 6-7 November

- **90 participants, 50% industry**
- **Poster session:**
  Draft conclusions from CEMCAP research work packages

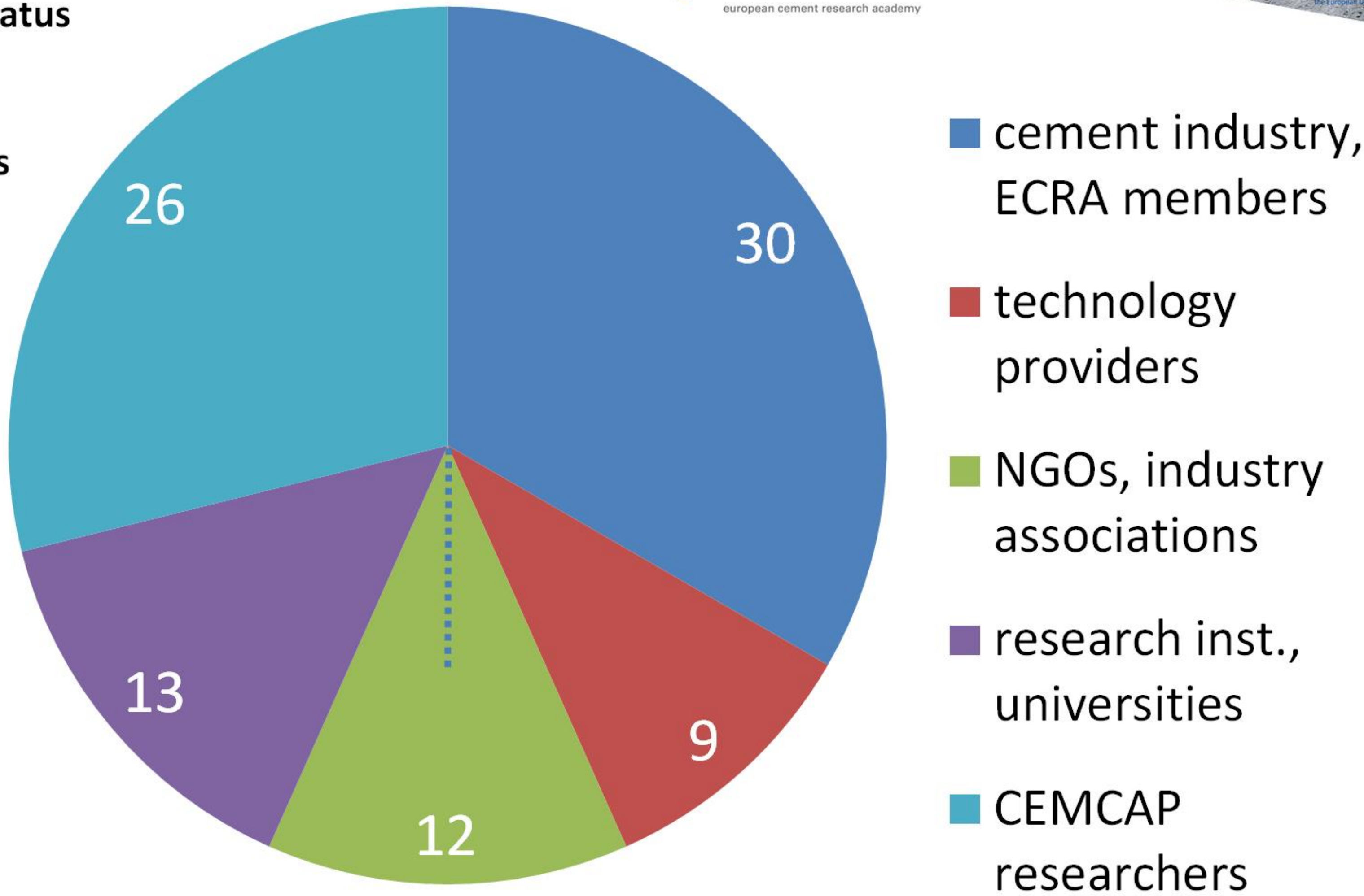
Presentations and discussions

- **Oxyfuel clinker cooler technology and experiment film**
- Calcium looping capture in the cement industry
- **Geological CO_2 storage**
- Membrane-assisted CO_2 liquefaction
- Commercial use of captured CO_2 and CCU options for the cement industry
- Direct separation technology for capturing process CO_2 emissions, H2020 project LEILAC
- The full-scale CCS project at Norcem Brevik:
  Can it be realized?
- EU CCS policy and possibilities for R&I funding

https://ecra-online.org/seminars-and-events/overview/

2nd ECRA/CEMCAP Workshop
Duesseldorf, 6-7 November
Registration status
2017-10-25

90 participants
50% industry



To follow CEMCAP:

- Public deliverables are uploaded to our website: www.sintef.no/cemcap/results
  - CEMCAP Framework document
  - Oxyfuel clinker cooler film
- On twitter (@cemcap_co2) we announce newly published deliverabes, newsletters, blogs and other CEMCAP-related info and events
- Subscribe to newsletters: send an e-mail to cemcap@sintef.no
- Final CEMCAP/ECRA workshop in Brussels mid-October 2018 (before GHGT-14)

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