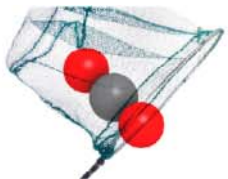


HiPerCap Workshop September 14, 2017

CEMCAP – making CO₂ capture retrofittable to cement plants

Kristin Jordal

SINTEF Energy Research

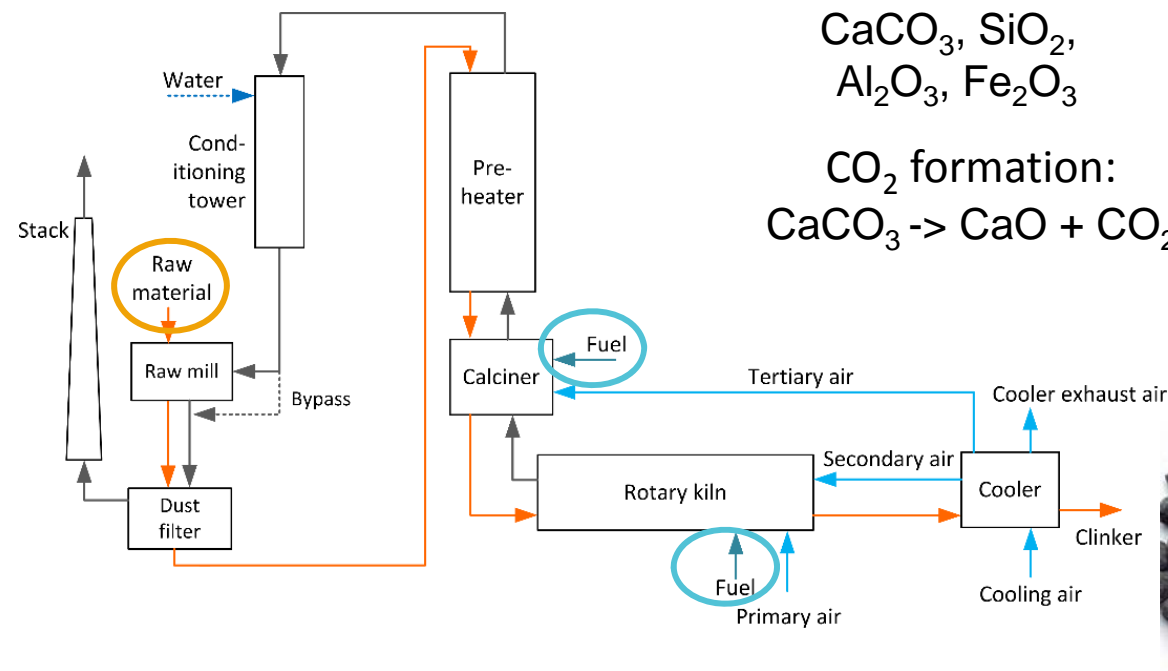


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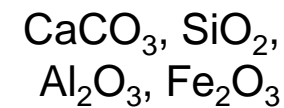


Introduction: CO₂ emissions from cement production

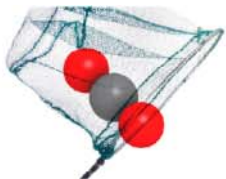
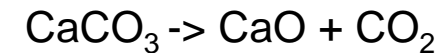
- Cement production constitute ~5-7% of global anthropogenic CO₂ emissions
- ~60% of the cement plant CO₂ comes from the raw material
- Fuel substitution is not enough for deep emission cuts



Raw materials:



CO₂ formation:

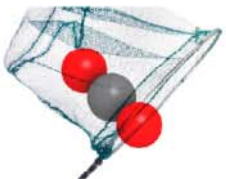


CEMCAP



CEMCAP metrics

- Project duration: May 2015-October 2018
- Budget: 10 030 kEUR
- EC contribution: 8 779 kEUR
- Swiss government funding 704 kEUR
- Industrial funding 547 kEUR
- Coordinator: SINTEF Energy Research



CEMCAP



CEMCAP Consortium

Cement Producers

Italcementi, IT

Norcem, NO

HeidelbergCement, DE

Technology Providers

GE Carbon Capture (GE-DE), DE

GE Power Sweden (GE-SE), SE

IKN, DE

ThyssenKrupp Industrial Solutions, DE

Research Partners

SINTEF Energy Research, NO

ECRA (European Cement Research Academy), DE

TNO, NL

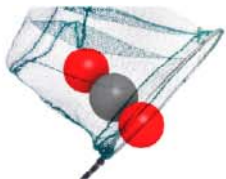
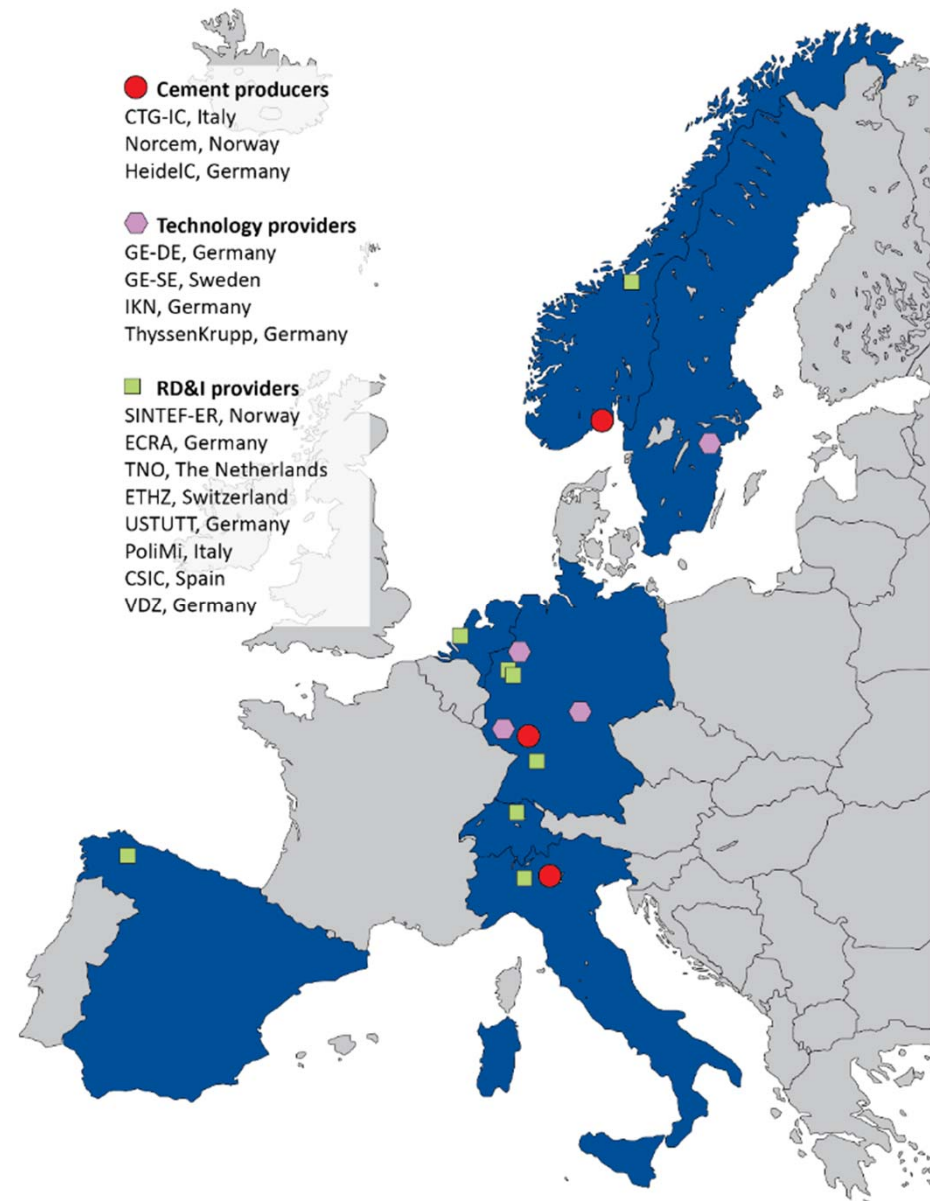
EHTZ, CH

University of Stuttgart, DE

Politecnico di Milano, IT

CSIC, ES

VDZ, DE



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Co-funded by
the European Union

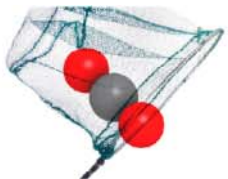
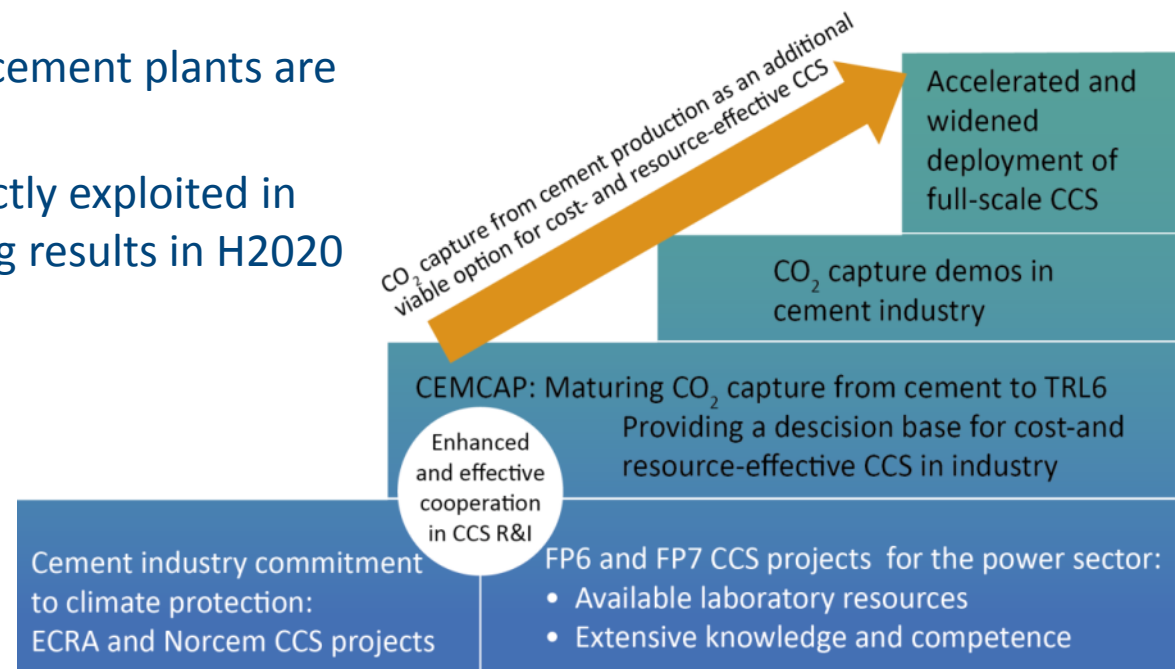
CEMCAP ambition

CEMCAP will deliver strategic conclusions for how to progress CO₂ 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

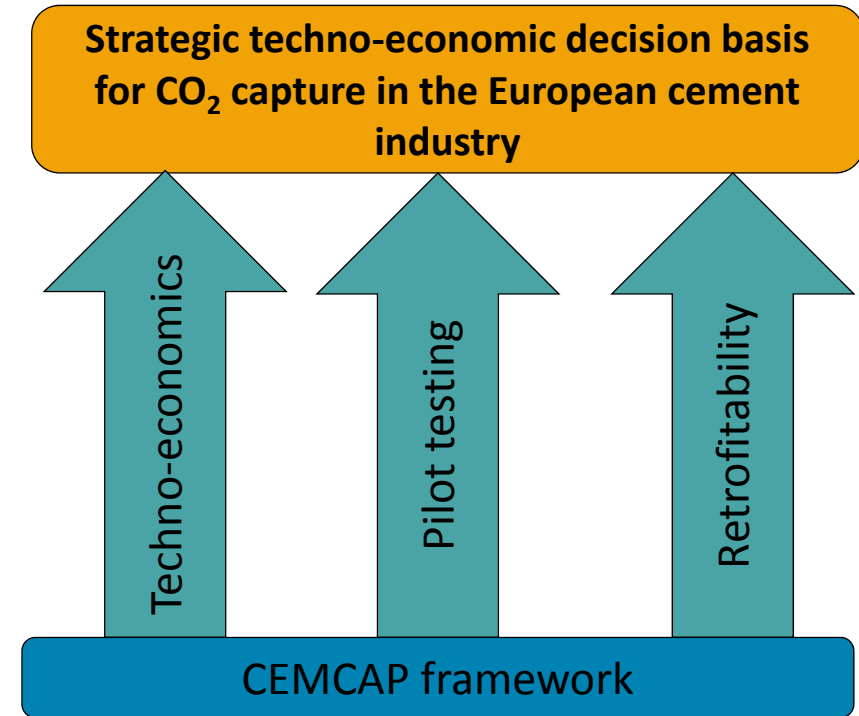
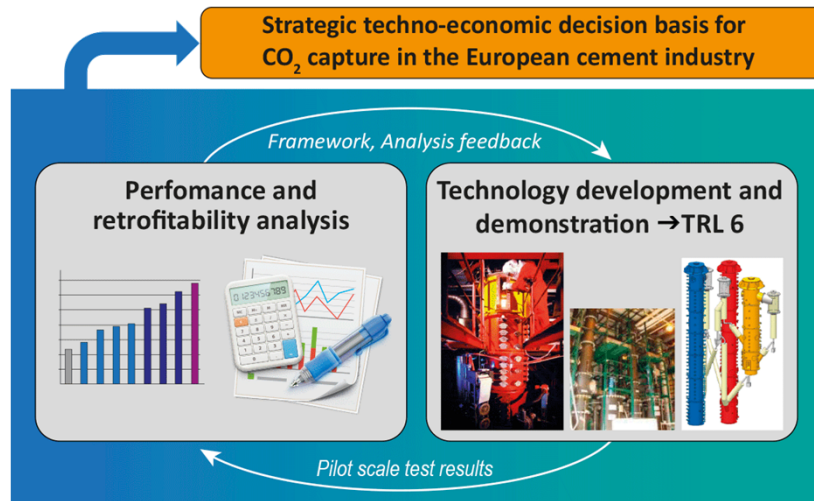
CEMCAP oxyfuel results will be directly exploited in the ECRA CCS project, Ca-looping results in H2020 CLEANER project



CEMCAP

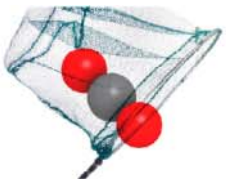


Project concept and outcome



Capture technologies in CEMCAP:

- Oxyfuel capture
- Chilled ammonia process
- Membrane-assisted CO₂ liquefaction
- Calcium looping

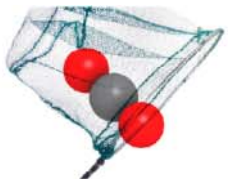


Retrofitability: cement plants differ in construction, raw material, fuel et.c.
E.g. the capture technology suitable for Norcem in the Norwegian full-scale project is not suitable for all other cement plants

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Analytical CEMCAP research

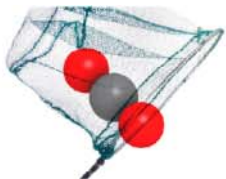



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CEMCAP framework: ready for use!

- "EBTF" for cement plants
- For consistent comparative assessment of capture technologies
- Provides information relevant for experimental and simulation work
- Defines:
 - A reference cement burning line
 - Specs for standard process units
 - Utilities description, cost and climate impact
 - Extent of capture and CO₂ specs
 - Economic parameters
 - Key performance parameters



CEMCAP


Grant Agreement Number:
641185

Action acronym:
CEMCAP

Action full title:
CO₂ 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 CO₂ capture from cement plants

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

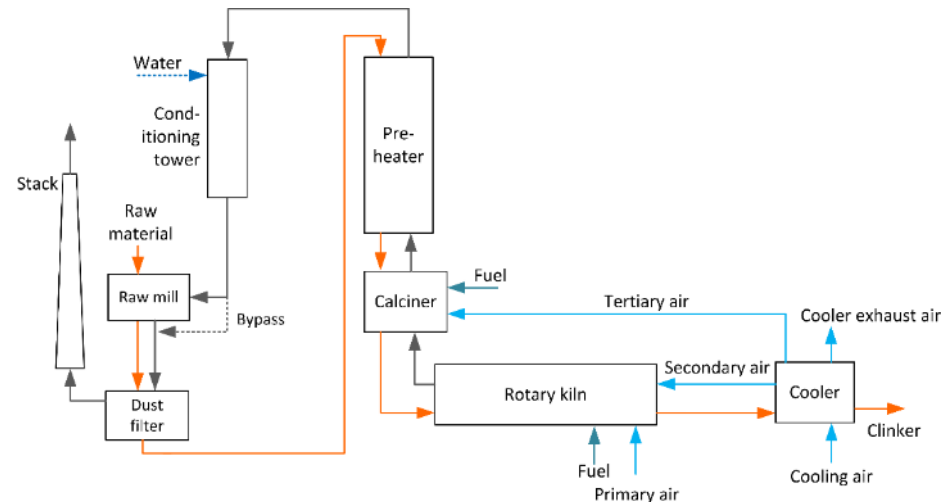
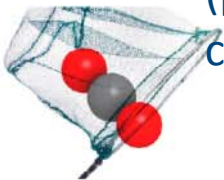
Organisation name of lead participant for this deliverable:
SINTEF-ER

| Project co-funded by the European Commission within Horizon2020 | | |
|-----------------------------------------------------------------|---------------------------------------------------------------------------------------|---|
| Dissemination Level | | |
| PU | Public | x |
| CO | Confidential , only for members of the consortium (including the Commission Services) | |

Download from
www.sintef.no/cemcap/results

Comparative capture process analysis (benchmarking)

- Concluded and available 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)
- Concluded but still confidential:
 - First process simulations with CO₂ capture have been done and compared, and feedback provided to partners (intermediate results, therefore confidential)
 - Costing methodology report (preliminary, therefore confidential)



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

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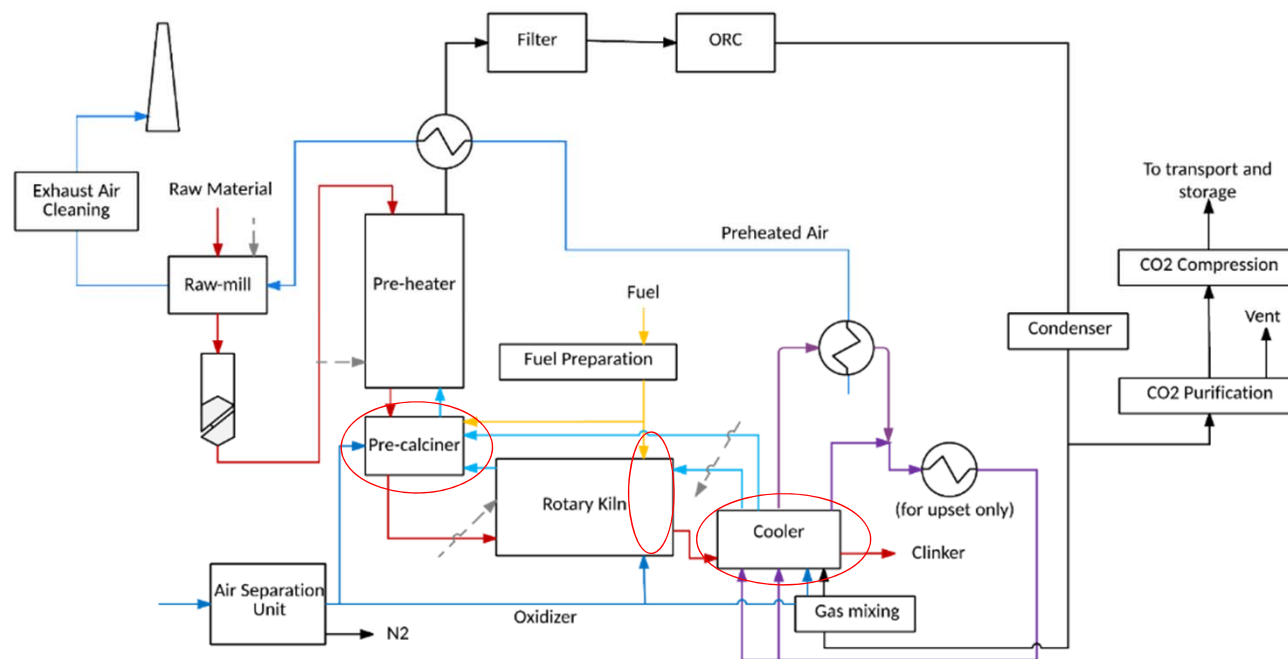


Process analysis example: Oxyfuel modelling

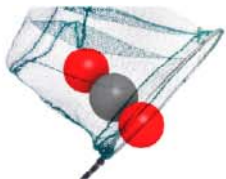
Purpose: Optimization of the oxyfuel clinker burning process based on process modeling verified by prototype results

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



Pre-calciner,
burner and
clinker cooler
tested in CEMCAP



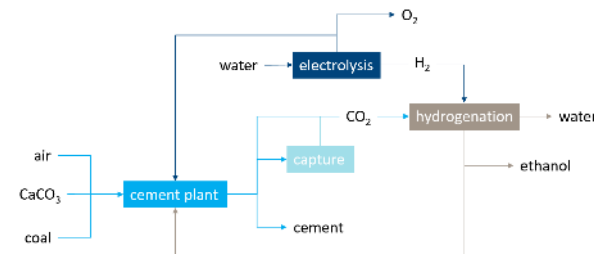
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Post capture CO₂ management

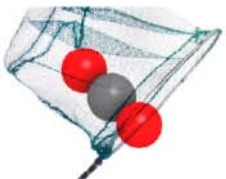
(what to do with the captured CO₂ if you are in the cement industry?)

- Cement-production post-capture CO₂ management routes investigated in CEMCAP:

1. CCS: Geological sequestration: option to be defined (TNO)
2. CCS: Mineralization to MgCO₃ (ETH Zurich)
3. CCU: CO₂ hydrogenation to ethanol (TNO)
4. CCU: CO₂ polymerization to Poly(propylene carbonate) (TNO)
5. CCU: food-grade CO₂ (TNO)



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

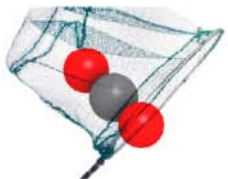


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Experimental CEMCAP research

Oxyfuel capture



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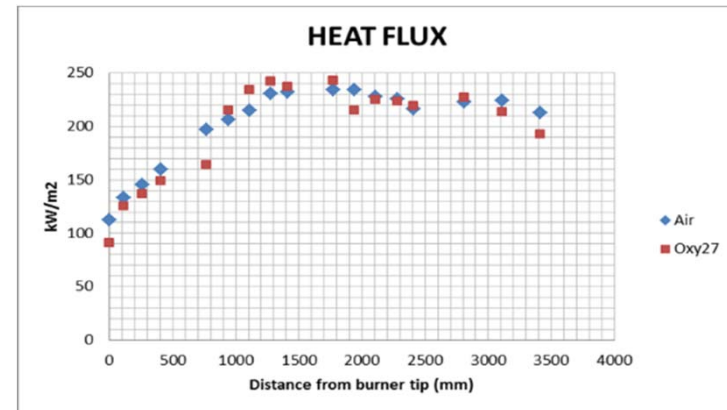
Oxyfuel cement burner tests



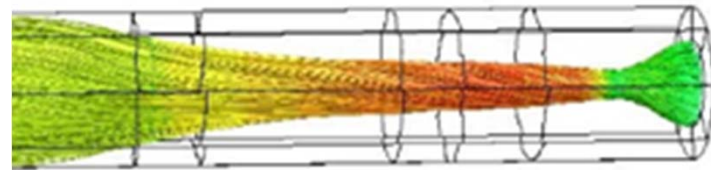
Oxyfuel burner design by ThyssenKrupp for cement plant operating conditions



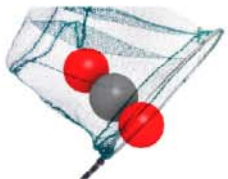
Oxyfuel burner testing at IFK, University of Stuttgart



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.

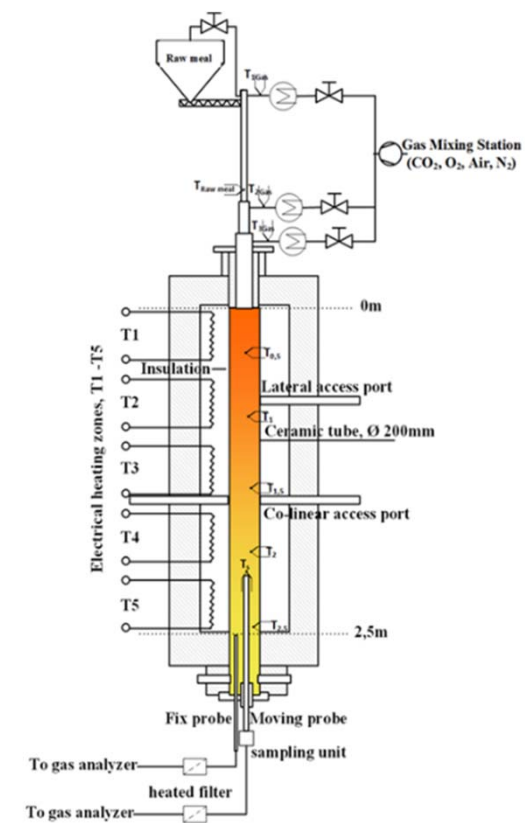
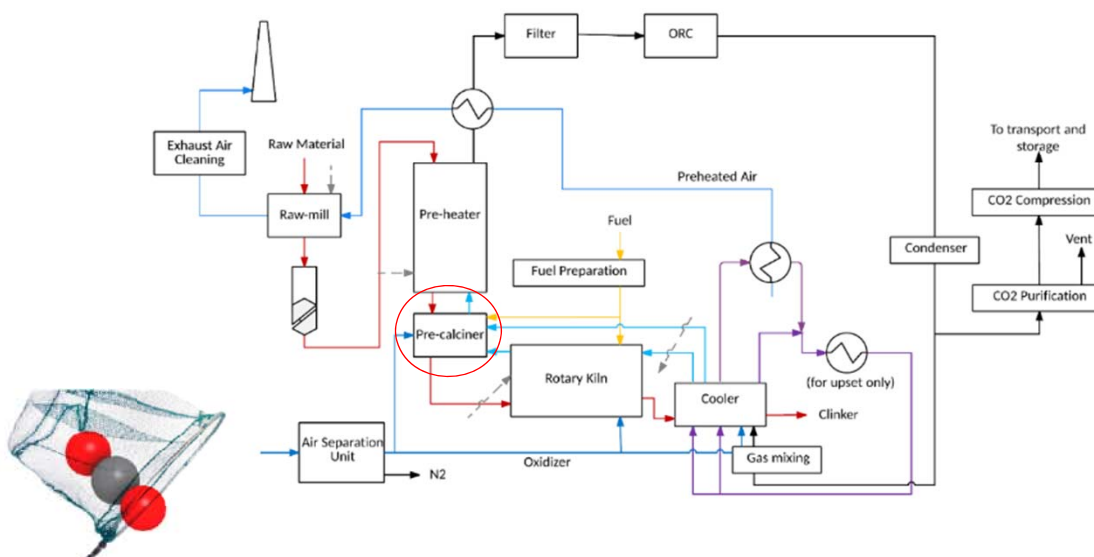


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Calciner technology for oxyfuel capture

- 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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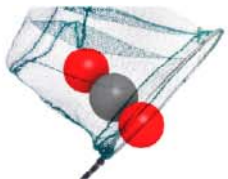
Oxyfuel clinker cooler – designed, built, tested



Clinker cooler prototype and recirculation system installation at HeidelbergCement in Hannover



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



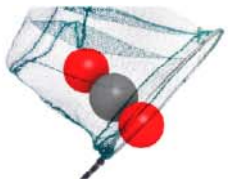
Clinker analysis is ongoing

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Experimental CEMCAP research

Post combustion capture

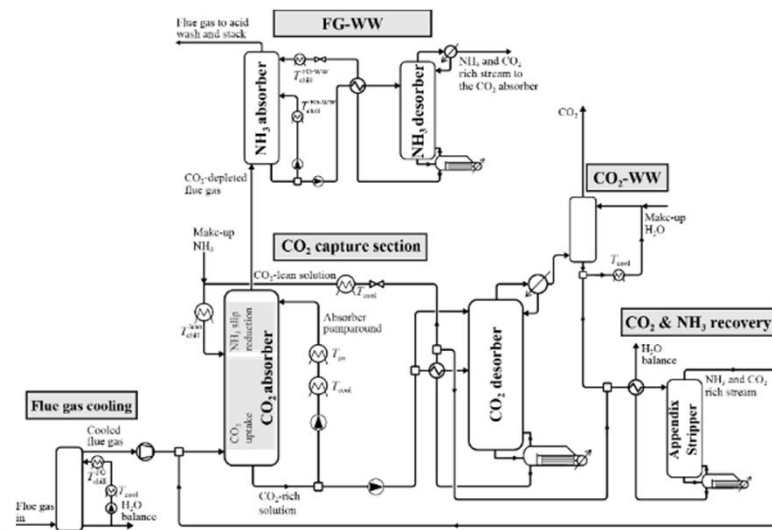


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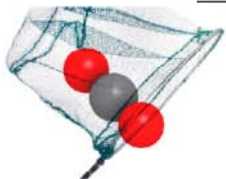
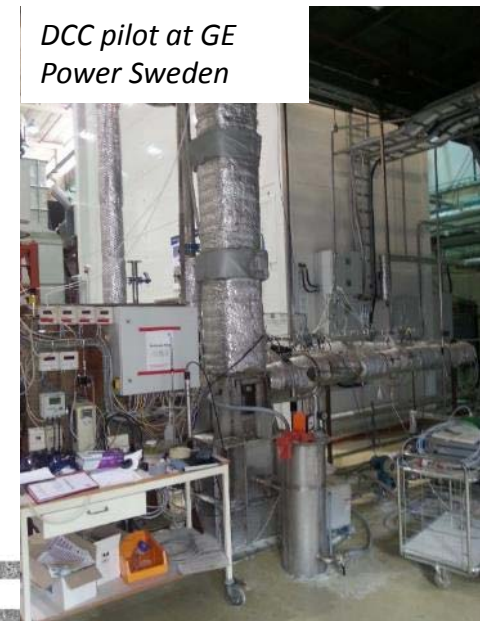
Chilled ammonia for cement plant CO₂ capture

- ETHZ has simulated and adapted the CAP system to different cement-plant flue gases; a 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

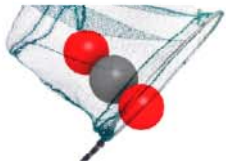
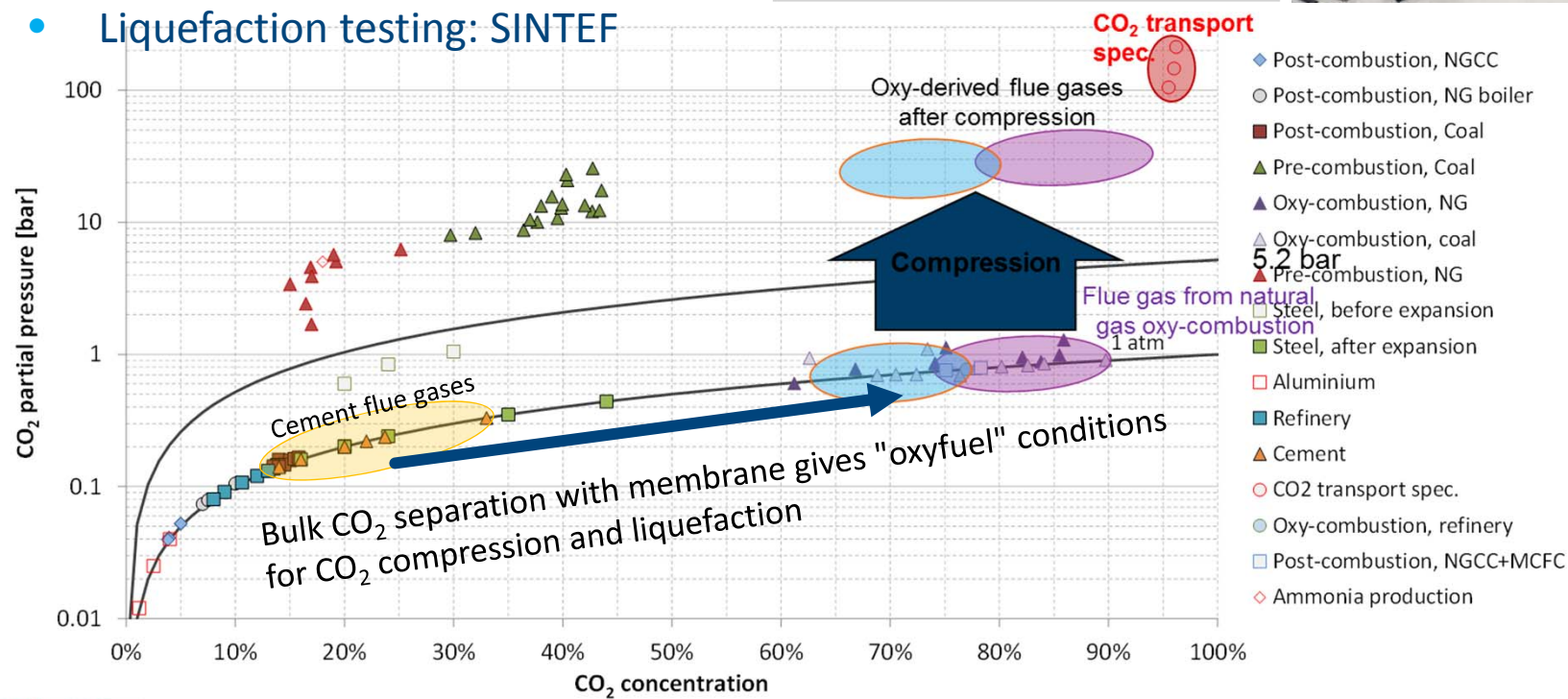
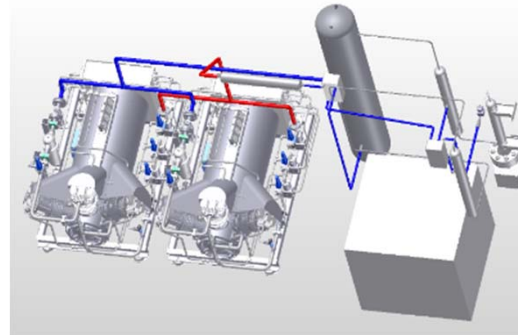
DCC pilot at GE Power Sweden



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Membrane-assisted CO₂ liquefaction

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

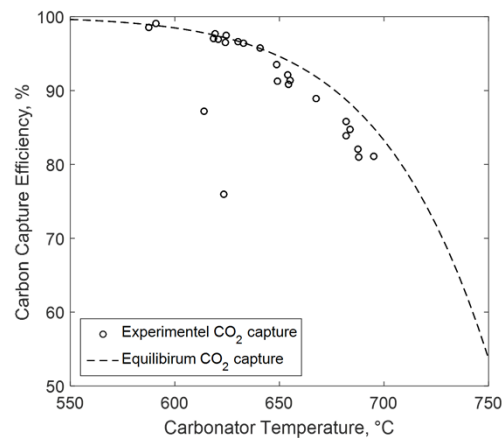


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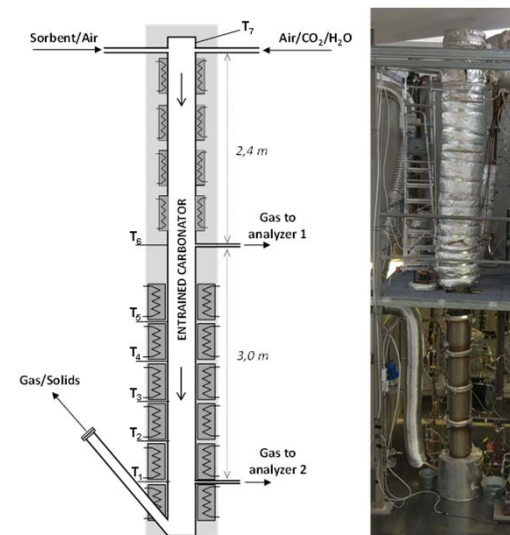


Calcium looping for cement plants

- Tail-end CO₂ capture: tests at 200 kW Ca-looping CFB test facility at IFK/Stuttgart University
- Entrained-flow (integrated) Ca-looping: tests at CSIC

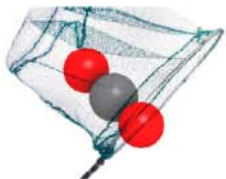


Experimental results on CaL CO₂ capture efficiency versus equilibrium CO₂ capture (IFK/USTUTT)



Experimental setup at CSIC

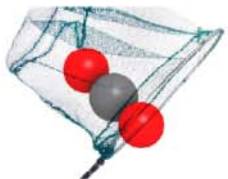
- Process simulations/sizing of full-scale Ca-looping conducted alongside exp work (Politecnico di Milano)
- "Spin-off project" H2020 CLEANER



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To conclude

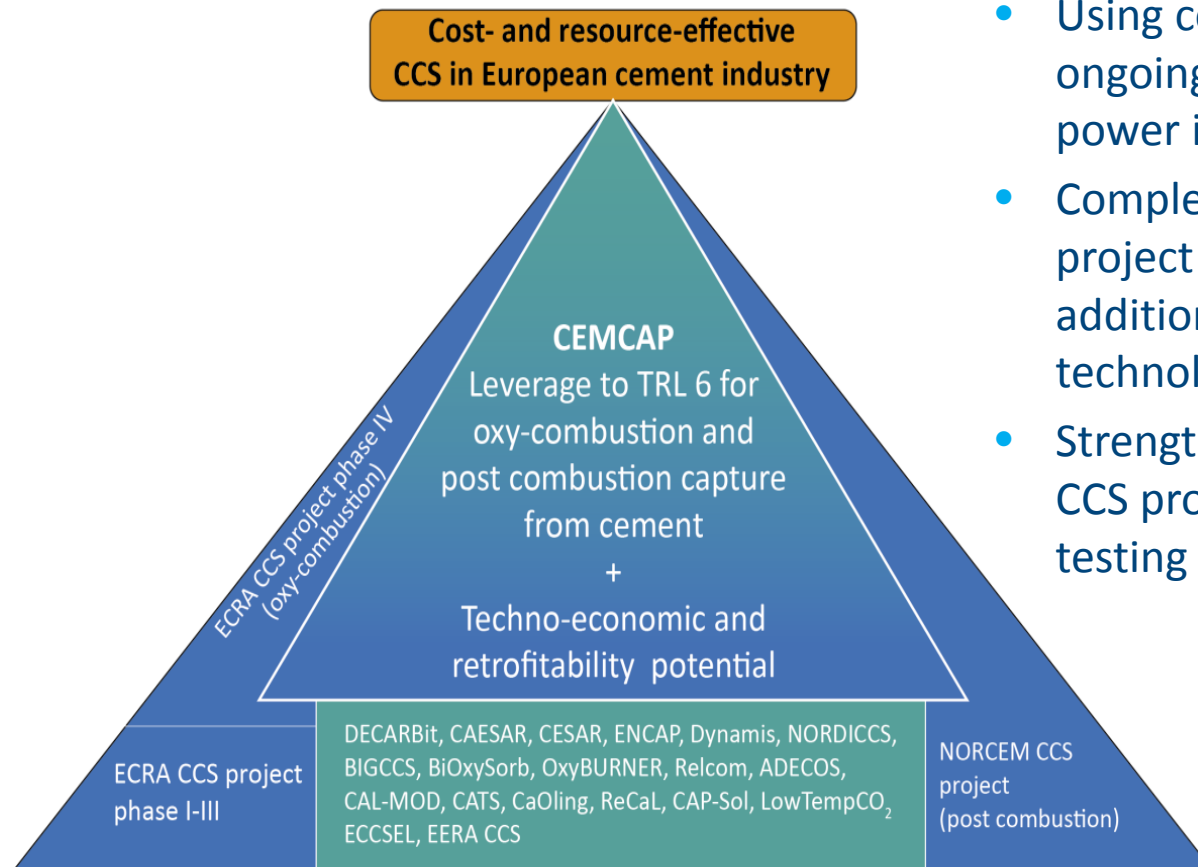


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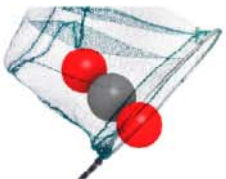
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CEMCAP background and contributions to CO₂ capture for cement



CEMCAP is

- Using competence and knowledge from ongoing and concluded CCS projects for power industry
- Complementing the Norcem CCS project by testing and evaluating additional post-combustion capture technologies
- Strengthening and advancing the ECRA CCS project for through component testing for oxyfuel CO₂ capture

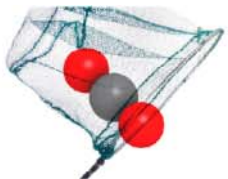
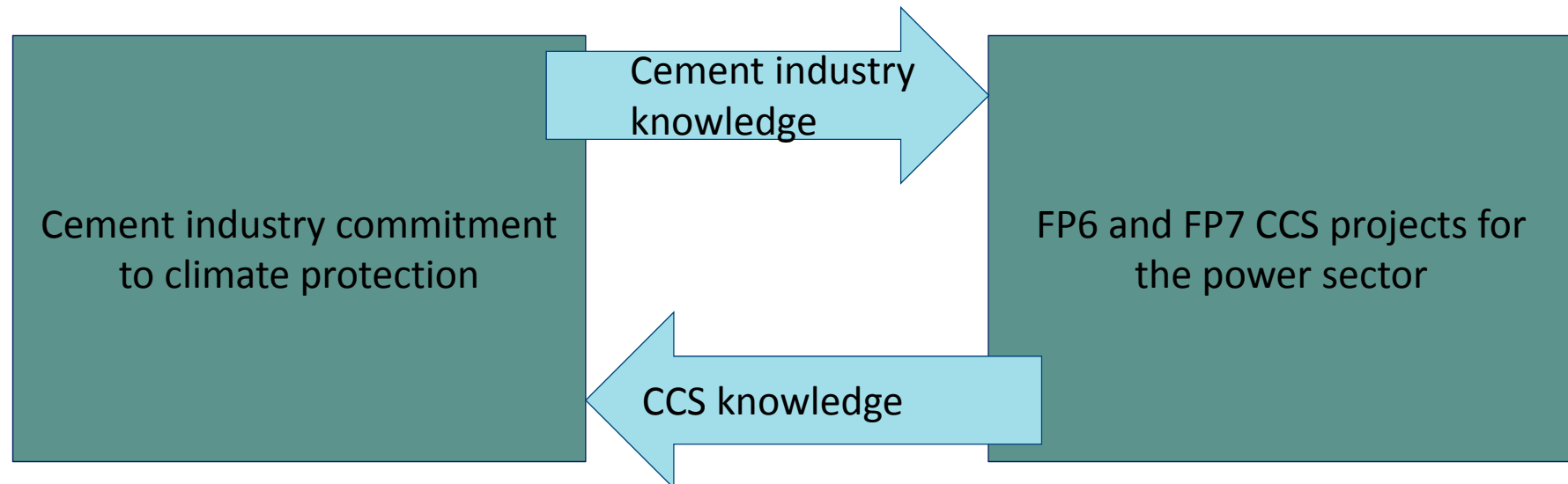


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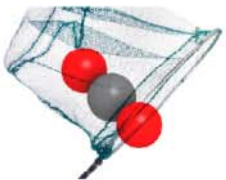
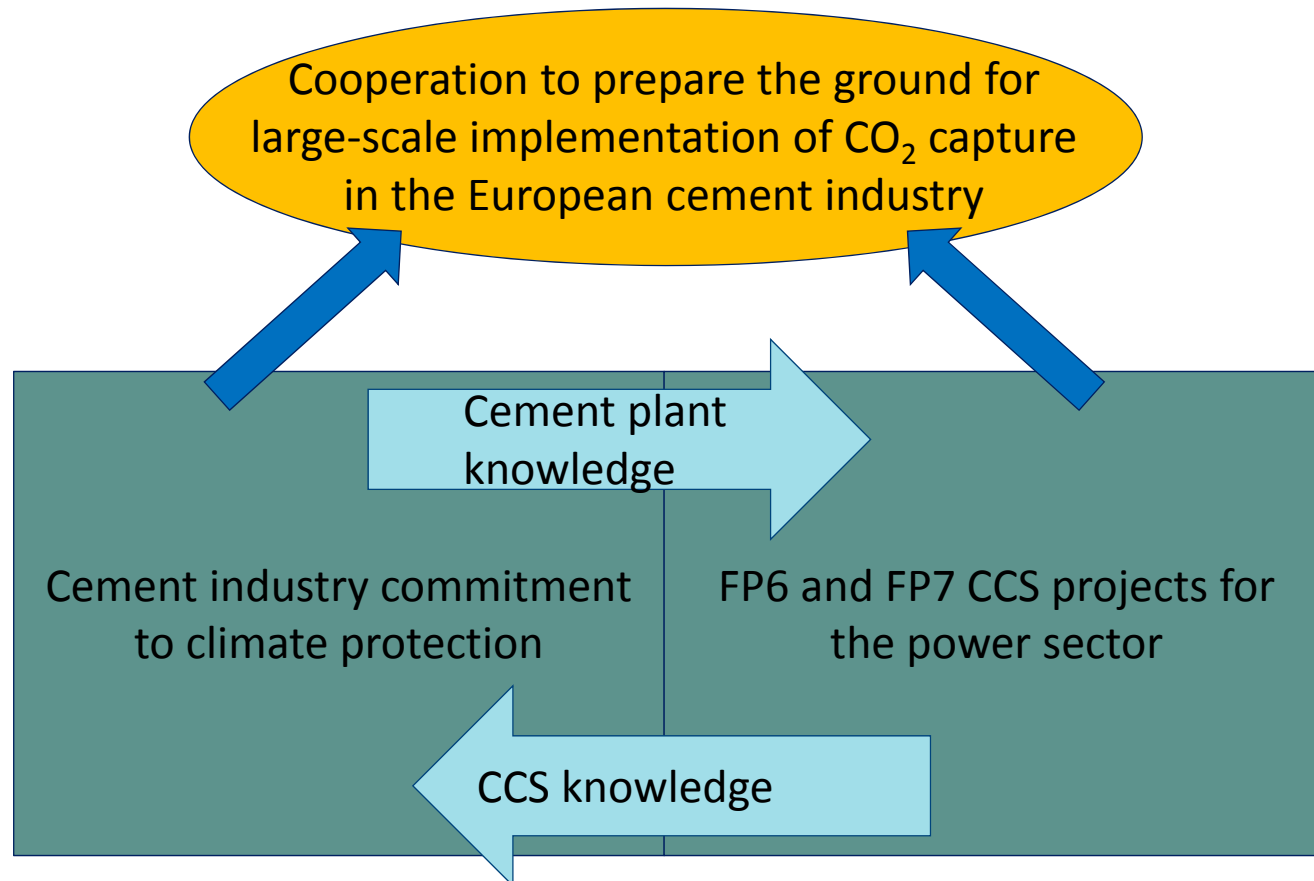
In CEMCAP a pool of CCS expertise has been made available to the cement industry



CEMCAP



In CEMCAP a pool of CCS expertise has been made available to the cement industry



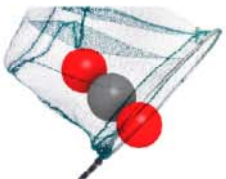
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First CEMCAP joint workshop with ECRA



September 2015 – focus on knowledge transfer between cement production and CCS experience, including a study tour to the HeidelbergCement plant in Lixhe, BE



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Coming soon: Second CEMCAP joint workshop with ECRA

Düsseldorf, November 6-7

November 6: informal light buffet and CEMCAP poster session, focus on technical results and preliminary conclusions

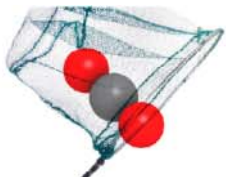
November 7: full day with presentations covering

- Curbing of industrial CO₂ emissions
- CEMCAP (post combustion, oxyfuel, clinker cooler film, industrial perspectives)
- Norcem CCS project
- H2020 project LEILAC
- EU CCS policy

Registration:

<http://www.sintef.no/projectweb/cemcap/events/>

Final CEMCAP/ECRA workshop in Brussels mid-October 2018
(before GHGT-14)

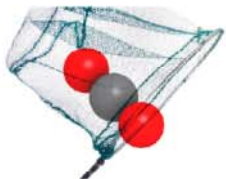


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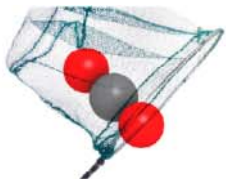
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 641185

This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 15.0160

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