CEMCAP – making CO$_2$ capture retrofittable to cement plants

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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:
CaCO₃, SiO₂, Al₂O₃, Fe₂O₃

CO₂ formation:
CaCO₃ → CaO + CO₂
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 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
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 CLEANKER project
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
Analytical CEMCAP research
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

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
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 CO₂ in the plant, to enable capture of highly concentrated CO₂

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

Oxyfuel capture
Oxyfuel cement burner tests

Oxyfuel burner design by ThyssenKrupp for cement plant operating conditions

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
Oxyfuel clinker cooler – designed, built, tested

Clinker cooler prototype and recirculation system installation at HeidelbergCement in Hannover

Clinker analysis is ongoing

Hot commissioning of the oxyfuel clinker cooler and first oxyfuel clinker samples
Experimental CEMCAP research

Post combustion capture
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
Membrane-assisted CO₂ 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
- Entrained-flow (integrated) Ca-looping: tests at CSIC

![Graph](image)

*Experimental results on CaL CO\(_2\) capture efficiency versus equilibrium CO\(_2\) capture (IFK/USTUTT)*

- Process simulations/sizing of full-scale Ca-looping conducted alongside exp work (Politecnico di Milano)
- "Spin-off project" H2020 CLEANER
To conclude
CEMCAP background and contributions to CO$_2$ 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 CO$_2$ capture
In CEMCAP a pool of CCS expertise has been made available to the cement industry
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Cooperation to prepare the ground for large-scale implementation of CO₂ capture in the European cement industry.

- Cement industry commitment to climate protection
- FP6 and FP7 CCS projects for the power sector
- CCS knowledge
- Cement plant knowledge
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
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)
To follow CEMCAP:

• Public deliverables are uploaded to our website: [www.sintef.no/cemcap](http://www.sintef.no/cemcap)

• On twitter (@cemcap_co2) we announce newly published deliverables, newsletters, blogs and other CEMCAP-related info and events

• Subscribe to newsletters: send an e-mail to [cemcap@sintef.no](mailto:cemcap@sintef.no)
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