Preparing the ground for CCS in the European cement industry – CEMCAP status

Kristin Jordal\textsuperscript{1}, Sigmund Størset\textsuperscript{1}, Helmut Hoppe\textsuperscript{2}, Mari Voldsund\textsuperscript{1}, Giovanni Cinti\textsuperscript{3}, Per Brevik\textsuperscript{4}, Juliana Montero\textsuperscript{5}, Armin Jamali\textsuperscript{2}, Rahul Anantharaman\textsuperscript{1}, Francisco Carrasco\textsuperscript{6}, Eike Willms\textsuperscript{7}, Manoj Paneru\textsuperscript{7}, Marco Lindemann Lino\textsuperscript{2}, Simon Becker\textsuperscript{8}, Rob van der Meer\textsuperscript{9}, Francisco Perezcalvo\textsuperscript{10}, Ola Augustsson\textsuperscript{11}, David Berstad\textsuperscript{1}, Matthias Hornberger\textsuperscript{6}

\textsuperscript{1}SINTEF Energy Research, \textsuperscript{2}VDZ GmbH, \textsuperscript{3}Italcementi, \textsuperscript{4}Norcem, \textsuperscript{5}TNO, \textsuperscript{6}IFK – University of Stuttgart, \textsuperscript{7}ThyssenKrupp Industrial Solutions, \textsuperscript{8}IKN, HeidelbergCement, \textsuperscript{10}ETH Zürich, \textsuperscript{11}GE Power Sweden
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 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 approach: iteration between analytical and experimental research

**Analytical work**
- Framework document
- Capture process simulations
- Simulations of full cement plants (kilns) with CO₂ capture
- Cost estimations/benchmarking
- Retrofitability analysis

**Experimental work**
- Testing of three components for oxyfuel capture (linked to ECRA CCS project)
- Testing of three different post-combustion capture technologies
- ~10 different experimental rigs
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
CEMCAP structure
WP3: CEMCAP framework – finished and ready for sharing!

- 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

"A framework for CO₂ capture from cement production"
Presentation by Mari Voldsund, Session D2, 14.00
WP4 Comparative capture process analysis

- 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)

- Ongoing or confidential:
  - First process simulations with \( \text{CO}_2 \) capture have been done and compared, and feedback provided to partners (intermediate results, therefore confidential)
  - Costing methodology report (preliminary, therefore confidential)

- Remaining work:
  - Retrofitability study
  - Final techno-economic comparison
WP5 – Post capture CO₂ management

- 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)

"CO₂ utilization by Ethanol production in the Cement Industry"
Presentation by Juliana Monteiro, session D5, 13.00
WP6: 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

Pre-calciner, burner and clinker cooler tested in CEMCAP
WP7: 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.

"Investigations on oxyfuel combustion in a cement kiln prototype burner"
TCCS-9 poster by Francisco Carrasco
WP8: 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 ongoing
WP9: 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

A clinker cooler film is under preparation, will be published on YouTube
WP10: 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
WP11: Post combustion capture from cement: Membrane-assisted \(\text{CO}_2\) liquefaction

- End-of-pipe technology (requires De-SOx, De-NOx, dehydration)
- No fuel input, only power
- Membrane testing: TNO
- Liquefaction testing: SINTEF
WP12: 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

- Process simulations/sizing of full-scale Ca-looping conducted alongside exp work

"CCS in cement industry – Application of the Calcium Looping technology"
Presentation by Matthias Hornberger, Session D2, 15.00

"CO2 capture in cement plants by entrained flow reactors Ca-looping process" TCCS9 poster by Maurizio Spinelli
To conclude: CEMCAP – aiming to be a visible project with an impact

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 CLEANKER project

CEMCAP framework: a useful reference for any study on CO₂ capture from cement
To follow CEMCAP:

• Public deliverables are uploaded to our website: 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

• **Open seminars** about CEMCAP results, organised jointly with ECRA:
  • Tentatively: 7 November 2017, in Düsseldorf
  • Mid-october 2018 in Brussels (final CEMCAP/ECRA workshop)

• Seminars will be announced on the website, in newsletters and on Twitter
Acknowledgements
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

www.sintef.no/cemcap
Twitter: @CEMCAP_CO2
Newsletter subscription, inquiries: cemcap@sintef.no