CEMCAP — a Horizon 2020 project on retrofittable CO2 capture from cement plants

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Introduction and Framework
CO₂ emissions in the cement industry

- Cement production constitutes ~ 5 % of global anthropogenic CO₂ emissions
- In 2013 ~ 20 % of global CO₂ emissions from cement production originated from Europe
The need for CCS in Cement production

Without reduction measures: 2.4 Gt/a in 2050
BLUE MAP scenario (with CCS): max 1.6 Gt/a in 2050

Reduction by:
- Increase of energy efficiency
- Alternative fuels use
- Reduction of clinker share

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
CEMCAP Consortium

**Cement Producers**
CTG (Group Technical Centre of 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
ETHZ, CH
University of Stuttgart, DE
Politecnico di Milano, IT
CSIC, ES
VDZ, DE
CEMCAP – positioned to complement and strengthen the Norcem and ECRA CCS projects

CEMCAP will
• Utilize competence and knowledge from ongoing and concluded CCS projects for power industry
• Complement the Norcem CCS project by testing and evaluating additional post-combustion capture technologies
• Strengthen and advance the ongoing ECRA CCS project for cement industry (component testing for oxyfuel)
Project structure

Framework, evaluation, management and dissemination (M1-42)

- Project management, dissemination and exploitation SP1
  - Project management and coordination WP1
  - Dissemination and exploitation WP2

- Framework and comparative analysis SP2
  - CEMCAP framework WP3
  - Comparative capture process analysis WP4
  - Post-capture CO₂ management WP5

Technology development and demonstration → TRL6 (M1-36)

- Oxyfuel capture retrofit SP3
  - Oxyfuel modelling and optimisation WP6
  - Oxyfuel burner technology WP7
  - Calciner technology for oxyfuel capture WP8
  - Oxyfuel clinker cooler prototype WP9

- Post combustion capture retrofit SP4
  - Chilled ammonia process (CAP) WP10
  - Membrane-assisted CO₂ liquefaction WP11
  - Calcium looping (CAL) capture WP12
Project schedule

Q3 2015

- CEMCAP framework (WP3)
  - Experimental plans (WP7, 8, 9, 10, 11 and 12)
- Reference cement plant (WP4)

Q3 2016

- Capture technology process designs (WP6, 10, 11 and 12)
  - Pilot testing (WP7, 8, 9, 10, 11 and 12)
- First cement plant designs with CO₂ capture (WP4)

Q3 2017

- Further Pilot testing Reaching TRL6 (WP7, 8, 9, 10, 11 and 12)
  - Refined capture technology process designs (WP6, 10, 11 and 12)
- Final cement plant designs with CO₂ capture (WP4)
  - Cost for CO₂ capture technologies (WP4)

Q3 2018

- Comparative techno-economic analysis
  - Retrofitability analysis
  - Techno-economic decision base
  - CEMCAP innovations
  - Pathways for low-emission cement plants
CEMCAP framework: Reference plant

- Cement plants differ in size, process technology, operational mode, fuel mix, raw material composition influencing energy efficiency, flue gas characteristics etc.
- A reference kiln system has been defined, based on Best Available Techniques level including
  - 5-stage cyclone preheater
  - Calciner with tertiary air duct
  - Modern grate clinker cooler
- Representative average values of European cement plants define the key data:
  - Plant Size: 3000 t/d (1 Mt clinker/y)
  - Annual cement production: 1.36 Mt/y
  - Clinker/cement ratio: 73.7 %
  - 320 days of non-stop operation (85 % capacity rate), typically 3-4 weeks of winter revision
- The reference plant without CO$_2$ capture will be the basis for performance evaluation of all CEMCAP technologies (cost, energy consumption, CO$_2$ quality...).
SP3 – Oxyfuel capture
Oxyfuel cement plant

- CO₂ capture by N₂ free combustion
- Oxyfuel combustion influences:
  - Heat transfer in rotary kiln (gas atmosphere)
  - Calcination kinetics in pre-calciner (CO₂ partial pressure)
- New clinker cooler design required (operation with recycle gas)
Technologies to be tested - oxyfuel

**Oxyfuel burner**
Existing 500 kW\textsubscript{th} oxyfuel rig at USTUTT was modified for CEMCAP experiments

**Calciner test rig**
Existing <50 kW\textsubscript{th} entrained flow calciner (USTUTT) will be used for oxyfuel calcination tests

**Clinker cooler**
Drawings completed, is being built for on-site testing at HeidelbergCement in Hannover (summer 2016)

Partners: USTUTT, TKIS, SINTEF-ER

Partners: USTUTT, VDZ, IKN, CTG

Partners: IKN, HeidelC, VDZ
SP4 – Post Combustion Capture
Technologies to be tested – post-combustion capture

**Chilled Ammonia Process (CAP)**
Absorber tests at GE Power Sweden (never tested for such high CO₂ concentrations before, up to 35 %)

**Membrane assisted CO₂ liquefaction**
Novel concept, suitable for high CO₂ concentrations
Membrane tests: TNO
Liquef. tests: SINTEF-ER

**Ca-looping (USTUTT, CSIC rigs)**
End of pipe CaL as well as integrated CaL tests

**Partners:**
- ETHZ, GE-SE, GE-DE
- TNO, SINTEF-ER
- USTUTT, CTG, PoliMi, CSIC, IKN
Chilled Ammonia Process (CAP)

- CO₂ separation by cyclic absorption/desorption in NH₃
- Lower regeneration effort
- High sorbent stability

- Experimental work on:
  - CO₂ capture performance
  - Flue gas pretreatment
    - Cooling
    - Removal of impurities
  - NH₃ slip reduction

- Simulation work on:
  - Model enhancement and validation
  - Overall CAP simulation and optimization
Preliminary Results - Chilled Ammonia Process (CAP):

- Large scale testing at Växjö (500 m³/h)
- 50 pilot plant tests of the CO₂ absorber at different experimental conditions
Membrane assisted CO₂ liquefaction

- Membrane screening
- Experimental work on
  - Membrane performance
  - Liquefaction and purification process
- Simulation work on combined membrane- and liquefaction capture system
Calcium Looping (CaL)

- CO₂ separation by cyclic calcination/carbonation of CaCO₃
- Low efficiency penalty / separation cost due to efficient heat recovery / heat integration
- Synergies between cement plant and CaL

- Experimental work on
  - Sorbent screening
  - CO₂ capture performance
  - Entrained flow CaL system

- Simulation work on
  - Entrained flow carbonator
  - CaL integration into the cement plant
Preliminary Results - Calcium Looping (CaL):

**Calcium Looping (CaL)**

- Demonstration at 200 kW\(_{th}\) pilot plant at IFK, University of Stuttgart
- CO\(_2\) capture up to 95 % (near equilibrium capture rate)
Outlook

- CEMCAP results will be presented during GHGT-13 in Lausanne (9 contributions)
- Next CEMCAP/ECRA workshop in spring 2017
- Experimental work finished by Q4 2017
- Comparative techno-economic analysis by Q3 2018
- Newsletter subscription on website (www.sintef.no/cemcap)

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