CEMCAP – a Horizon 2020 project on CO$_2$ capture from cement production

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CO$_2$ emissions in the cement industry

- Cement production constitute ~5% of global anthropogenic CO$_2$ emissions
- In 2013 ~ 20% of global CO$_2$ 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

Global CO₂ emissions of the cement industry in Gt/a

Source: IEA Cement Roadmap

- 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
The CEMCAP objectives

The primary objective of CEMCAP is

*To prepare the ground for large-scale implementation of CO$_2$ capture in the European cement industry*

To achieve this objective, **CEMCAP will**

*Leverage to TRL6 for cement plants the oxyfuel capture technology and three fundamentally different post combustion capture technologies, all of them with a targeted capture rate of 90%.*

*Identify the CO$_2$ capture technologies with the greatest potential to be retrofitted to existing cement plants in a cost- and resource-effective manner, maintaining product quality and environmental compatibility.*

*Formulate a techno-economic decision-basis for CO$_2$ capture implementation in the cement industry, where the current uncertainty regarding CO$_2$ capture cost is reduced by at least 50%.*
CEMCAP metrics

• Horizon2020 project coordinated by SINTEF Energy Research
• Duration: May 1st 2015 – October 31st 2018 (42 months)
• Budget: € 10 million
• EC contribution € 8.8 million
• Swiss government contribution: CHF 0.7 million
• Number of partners: 15
CEMCAP Consortium

Cement Producers
CTG (Group Technical Centre of Italcementi), IT
Norcem, NO
HeidelbergCement, DE

Technology Providers
Alstom Carbon Capture (AL-DE), DE
Alstom Power Sweden (AL-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 relation to Norcem and ECRA CCS projects

Norcem CCS project: Testing of amine, membrane, solid sorbent, Ca-looping (post-combustion)

CEMCAP: testing of chilled ammonia, Ca-looping, membrane-assisted CO$_2$ – liquefaction

ECRA CCS project: focusing on oxyfuel retrofit in its current phase IV

CEMCAP: testing of three key components for the oxyfuel plant

CEMCAP base: competence and knowledge from ongoing and concluded CCS projects for power industry
CEMCAP approach: iteration between analytical and experimental research

**Analytical work**
- 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
- Testing of three different post-combustion capture technologies
- ~10 different experimental rigs
Project structure
## Characteristics of technologies included in CEMCAP

<table>
<thead>
<tr>
<th>CO₂ capture principle</th>
<th>Oxyfuel capture</th>
<th>Post combustion capture technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Combustion in oxygen (not air) gives a CO₂-rich exhaust</td>
<td>Chilled ammonia</td>
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<tr>
<td></td>
<td>NH₃/water mixture used as liquid solvent, regenerated through heat addition</td>
<td>Polymeric membrane for exhaust CO₂ enrichment followed by CO₂ liquefaction</td>
</tr>
<tr>
<td>Cement plant integration</td>
<td>Retrofit possible through modification of burner and clinker cooler</td>
<td>Retrofit appears simple, minor modifications required for heat integration</td>
</tr>
<tr>
<td>Clinker quality</td>
<td>Maintained quality must be confirmed</td>
<td>Unchanged</td>
</tr>
<tr>
<td>CO₂ purity and capture rate</td>
<td>CO₂ purification unit (CPU) needed. High capture rate and CO₂ purity possible (trade-off against power consumption).</td>
<td>Very high CO₂ purity, can also capture NOx, SOx. High capture rate possible.</td>
</tr>
</tbody>
</table>
Technologies to be tested - oxyfuel

**Oxyfuel burner**
Existing 500 kWth oxyfuel burner at USTUTT to be modified for CEMCAP

**Calciner test rig**
Existing <50 kWth entrained flow calciner (USTUTT) to be used for oxyfuel calcination tests

**Clinker cooler**
To be designed and built for on-site testing at HeidelbergCement in Hannover

Partners: USTUTT, TKIS, SINTEF-ER

Partners: USTUTT, VDZ, IKN, CTG

Partners: IKN, HeidelC, VDZ
Technologies to be tested – post-combustion capture

**Chilled Ammonia Process (CAP)**
Tests at Alstom Power Sweden (never tested for such high CO₂ concentrations before)

**Membrane assisted CO₂ liquefaction**
- Membrane tests: TNO
- Liquefaction tests: SINTEF-ER

**Ca-looping** (USTUTT, CSIC rigs)

- Partners: ETHZ, AL-SE, AL-DE
- Partners: TNO, SINTEF-ER
- Partners: USTUTT, CTG, PoliMi, CSIC, IKN
CEMCAP final results

CEMCAP will deliver strategic conclusions for how to progress CO₂ capture from cement plants from pilot-scale testing to demonstration and implementation.

Recommendations will be given for different scenarios (i.e. different types of cement plants at different locations in Europe).

CEMCAP progress towards final results will be possible to follow for the interested public through blogs, newsletters, website, Facebook, Twitter, conferences and pop-science articles.
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.
• Reference kiln system is based on Best Available Techniques level including
  – 5-stage cyclone preheater
  – Calciner with tertiary air duct
  – Modern grate cooler

• Representative average values of European cement plants define the key facts:
  – Plant Size: 3000 t/d (1 Mt clinker/y)
  – Annual cement production: 1.36 Mt clinker/y
  – Clinker/cement ratio: 73.7 %
  – 320 days of non-stop operation (85 % capacity rate), typically 3-4 weeks of winter revision
Thermal energy demand of the cement industry

Specific thermal energy demand: 3,280 kJ/kg clinker (annual average)

30% substitution rate
Flue gas characteristics – CO$_2$ emissions

<table>
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<th>Reference plant – CO$_2$ emissions</th>
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<tbody>
<tr>
<td>Spec. indirect CO$_2$ from electricity</td>
<td>0.049 - 0.068 t CO$_2$/t cement</td>
</tr>
<tr>
<td>Spec. direct CO$_2$ from clinker production (incl. biogenic CO$_2$)</td>
<td>0.828 t CO$_2$/t clinker</td>
</tr>
<tr>
<td>EU-average: 0.862 t CO$_2$/t clinker</td>
<td></td>
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<tr>
<td>Total spec. CO$_2$ emissions incl. electricity</td>
<td>0.66 – 0.68 t CO$_2$/t cement</td>
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- CO$_2$ content in flue gas mainly influenced by thermal energy efficiency, fuel and raw material composition.
- Reference case:
  828,000 tCO$_2$/y per plant
  ~ 2550 tCO$_2$/d
- Total net CO$_2$ emissions in 2013: Germany: 15.7 Mt
  EU: 110 Mt
## Examples for flue gas compositions

<table>
<thead>
<tr>
<th>Component</th>
<th>Exhaust gas</th>
<th>From oxyfuel combustion</th>
<th>From Post-combustion</th>
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<tr>
<td></td>
<td>Conventional</td>
<td></td>
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<tr>
<td>CO₂</td>
<td>14 – 35 vol.%</td>
<td>95 vol.%</td>
<td>99.9 vol.%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>0.5 – 0.8 g/m³</td>
<td>&lt; 0.55 g/m³</td>
<td>&lt; 0.55 g/m³</td>
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<tr>
<td>SO₂</td>
<td>50 – 400 mg/m³</td>
<td>&lt; 4 mg/m³</td>
<td>&lt; 4 mg/m³</td>
</tr>
<tr>
<td>CO</td>
<td>0.1 – 2 g/m³</td>
<td>&lt; 0.3 g/m³</td>
<td>-</td>
</tr>
<tr>
<td>H₂O</td>
<td>6 – 10 vol.%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HCl</td>
<td>&lt; 20 mg/m³</td>
<td>-</td>
<td>-</td>
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Thank you for your attention!

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www.sintef.no/cemcap
Twitter: @CEMCAP_CO2