Global Experience with CCS Pilot Projects
CCS developments in cement: ECRA, Norcem

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ECRA: The European Cement Research Academy

ECRA is an internationally recognized European research body in the field of cement and concrete technology.

ECRA was founded in 2003:
- as a platform to stimulate and undertake research activities in the context of the production of cement and its application in concrete
- to facilitate and accelerate innovation to guide the cement industry by creating and disseminating knowledge from research.
- ECRA initiates and provides seminars and workshops teaching state-of-the-art knowledge on cement and concrete technology and communicating the latest research findings
- ECRA undertakes dedicated research projects
- ECRA focuses on issues which individual companies may not be able to tackle alone and are of major importance to the cement industry as a whole
ECRA: Successful seminars and workshops

**Examples of seminar/workshop topics**
- Alternative fuels and raw materials
- Grinding efficiency
- Clinker reactivity and cement performance
- \( \text{CO}_2 \) monitoring & reporting
- Process technology

**Seminars 2014**
- Alternative Fuels: Quality and environmental control
- Quality control of cement
- \( \text{CO}_2 \) monitoring and reporting: Methods, experiences and new developments
- Refractory materials and high temperature corrosion in the cement industry
- Hydration of blended cements

**Training Course 2014**
- Clinker and cement production
WBCSD/IEA cement technology roadmap 2009

4 Levers for CO₂ emissions reductions

- Energy efficiency 27%
- Alternative fuels (biomass) 19%
- Clinker substitution 9%
- Carbon Capture and Storage 46%
ECRA CCS project: Objectives

• Technical and economical feasibility of CCS technologies
• No focus on CO$_2$ transport and storage
• Integration of cement organisations: CSI, CEMBUREAU, PCA, etc.
• Joint research activities
• Cooperation with universities
ECRA CCS Project: Research Agenda

Phase I
- Literature study (January - June 2007)

Phase II
- Study about technical and financial aspects of CCS projects, concentrating on oxyfuel and post-combustion technology (summer 2007 – summer 2009)

Phase III
- Laboratory-scale / small-scale research activities (autumn 2009 – autumn 2011)

Phase IV
- Prepare pilot plant (time-frame: 2 - 3 years)

Phase V
- Build and operate pilot plant (time-frame: 3-5 years)

Phase VI
- Demonstration plant (time-frame: 3-5 years)
Oxy-fuel technology

- Combustion with pure oxygen instead of ambient air
- Flue gas recirculation to regulate temperature level
- Integrated system
- Doubling of the electrical energy demand per tonne of produced cement
- Thermal energy demand constant
Limiting factors by quality and durability requirements

- No serious influence on clinker composition
- Slight differences in cement properties (caused by Fe$^{2+}$) are in range of assured quality
- No negative influence on basic refractory material detected
- Using non-basic materials an increasing thermo-chemical reaction expected
- Adaption of refractory brickwork necessary
- Long-term test for evaluation advisable

No barriers expected from clinker quality and refractory durability
Flue gas conditioning decisive issues

- Main influencing parameter: degree of false air intrusion
- Cost of CO₂ compression and purification ranges
  - from about € 24 to about € 27/ton* depending on false air intrusion and CO₂ purity
- Capture rate of 90% possible.
  At higher cost level capture rates of 99% are achievable.
- Major intrusion from sealing locations like doors and poke holes

- Improved maintenance of these locations (gap reduction of 25%) would reduce intrusion to 6%.
- Singular sealing locations at kiln can be equipped with seal gas technology

Slight cost increase of CPU by impurities. Decrease of false air by improved maintenance sufficient

Not only CO₂ captured! SO₂, Nox, heavy metals, etc
Retrofitting boundaries

- Important aspect for the application of oxy-fuel in Europe
- Retrofitting an existing burner for oxy-fuel application is unlikely, but replacement by a suitable design is possible
- Designing a gas-tight two-stage cooler is feasible
- False air intrusion could be reduced to the greatest possible extent by overhauling/ replacing inspection doors and similar devices (< 6%)
- New safety and controlling devices necessary
- Space requirements of ASU/CPU
- Conventional behavior in trouble shooting restricted (no opening of doors/flaps in the plant etc.)

Less limiting factors for retrofitting than expected
Phase IV - Deliverables

Phase IV. A:
• Provide answers to the remaining challenges and further optimise the findings for a hypothetical medium sized plant (Work package A)

• Prepare the next steps towards a pilot kiln: work out detailed technical and economic concepts for a pilot-scale plant (Work package B)

Phase IV. B:
• Work out detailed technical and economic concepts concerning the retrofitting of a full-scale existing plant (Work package C)
## Phase IV.A - Work packages

<table>
<thead>
<tr>
<th>No.</th>
<th>Sub-package (short title)</th>
<th>Who?</th>
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</thead>
<tbody>
<tr>
<td>A 1</td>
<td>Simulation study</td>
<td>Research Institute</td>
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<td>A 3</td>
<td>Advanced cooler design</td>
<td>IKN</td>
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<td>A 4</td>
<td>Future oxygen supply</td>
<td>Danish Technical University</td>
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<td>A 5</td>
<td>Experimental verification of sealing potential</td>
<td>Irish Cement + Research Institute</td>
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<tr>
<td>B</td>
<td>Concept for a pilot plant:</td>
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<td>B 1</td>
<td>Plant capacity</td>
<td>Aixergee</td>
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<tr>
<td>B 2</td>
<td>Design principle</td>
<td>Aixergee</td>
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<tr>
<td>B 3</td>
<td>Dimensioning</td>
<td>CINAR + Fives FCB (supported by Research Institute)</td>
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<tr>
<td>B 4</td>
<td>Control and safety devices</td>
<td>n.n. (retendering)</td>
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<tr>
<td>B 5</td>
<td>Cost estimation</td>
<td>n.n. (retendering)</td>
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<tr>
<td>B 6</td>
<td>Concept for reuse</td>
<td>Subgroup</td>
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<tr>
<td>D1</td>
<td>CO₂ overall balance</td>
<td>Student work</td>
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<td>E</td>
<td>Coordination</td>
<td>Research Institute</td>
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Work package A1

- **Simulation study:**
- **Task assigned to:** Research Institute
- **Objectives:**
  - Integration of all findings from phase III
  - Simulation of different capacities and plant layouts, process fluctuation and application of alternative fuels/bypass
  - Concept for switching mode

**Progress:**

- Evaluation of impact of plant capacity/alt. fuels, false air ingress, ASU and condenser performance and recirculation rate on energy demand
- Concept for bypass system and switching mode

**Status:** Programming work and further simulations progressing
Advanced cooler design:

- Task assigned to: IKN

Objectives:
- Further development of advanced cooler concepts
- Minimizing the risks of the concepts of phase III
- Evaluation of acceptable gas-tightness

Progress:
- Two potential concepts developed and balanced (Intermediate Chute, Gas Recirculating Cooler)
- Evaluation of pro/cons, recommendations

Status: Final report in progress
Work package A5

- Experimental verification of sealing potential:
- Task assigned to: Irish Cement, Research Institute
- Objectives:
  - Experimental evaluation of best practice maintenance for false air reduction
  - Measurements (2 trials), long term inspection

Progress:
- Trials conducted and evaluated
- Identification of reference (15%) and improved maintenance (8%) false air intrusion level

Status: Student’s report available, long term inspection on-going
Work package B: Concept of a pilot plant

- B1: Suitable plant size
- B2: Design
- B3: Dimension
- B4: Control of and safety concept
- B5: Costs estimation
- B6: Concept for reuse of the plant
CCR: Utilization of captured CO$_2$ for MeOH or CH$_4$

CO$_2$ sources like power plants, cement plants, etc.

CO$_2$ capture technologies

H$_2$ production with regenerative energies

Methanol or methane production
Carbon capture project in Brevik

- The first capture project in the cement sector
- We are in need of more accurate knowledge
- Cement plants suitable for CO₂ capture
  - High concentration of CO₂
  - The flue gas is more “polluted”
  - Available heat energy from kilns
- Energy efficiency
- Costs (CAPEX and OPEX)
International project on behalf of the cement sector in Europe

Partners:
Norcem, HeidelbergCement og ECRA
(European Cement Research Academy)

Funding:
• State funding through Gassnova (Climit program): 75 %
• Total budget: 93 MNOK (11.7 M€)

Project period:
3, 5 years from May 2013
Four capture technologies for testing

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<thead>
<tr>
<th>Technology</th>
<th>Supplier</th>
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<tr>
<td>Amine technology</td>
<td>Aker Clean Carbon</td>
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<tr>
<td>Membrane technology</td>
<td>DNV KEMA, NTNU &amp; Yodfat Engineers</td>
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<td>Solid sorbent technology</td>
<td>RTI</td>
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<td>Calcium Cycle (Carbonate Looping, RCC)</td>
<td>Alstom Power</td>
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Cooperation with technology providers: ACC

- Amine scrubbing technology

- **Mobil Test Unit (MTU)**
  - 40 foot container
  - Absorption tower: 25 m
  - Stripper: 13.4 m

- **Capacity: 2,000 t CO\(_2\)/ year**