Challenges to the Deployment of CCS in the Energy Intensive Industries
(Part 2: Cement Industry Sector)

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Cement manufacture at a glance

Cement is a man-made powder that, when mixed with water and aggregates, produces concrete. The cement-making process can be divided into two basic steps:

1. Clinker is made in the kiln at temperatures of 1,450°C
2. Clinker is then ground with other minerals to produce the powder we know as cement

Source: WBCSD Cement Technology Roadmap 2009
Direct CO₂ Emissions Reduction - UK cement

MPA Cement Reduction in Absolute Carbon Dioxide Emissions
1990 to 2010

[Graph showing a downward trend in CO₂ emissions from 14,000,000 tonnes in 1990 to 5,000,000 tonnes in 2010.]

mpa cement
Direct CO₂ emissions - clinker

Carbon Dioxide Emission from Clinker Production

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcination (Process) CO₂ %</td>
<td>61</td>
</tr>
<tr>
<td>Combustion (Fuel) CO₂ %</td>
<td>39</td>
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</tbody>
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Cement industry research

- Cement emission ~25% CO₂
- IEA GHG - UK Cement industry Study
- CCS Cement plant will cost double a non-CCS cement plant
- Operational costs also double
- Need for transport infrastructure
- Technical barriers for Oxyfuel and post combustion
- Need for funding
CO₂ CAPTURE IN THE CEMENT INDUSTRY

Technical Study
Report Number: 2008/3
Date: July 2008
Cement Production

\[
\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
\]

- **Raw meal** (limestone etc)
- **Mill and drier**
- **Preheaters** (multiple stages)
- **Precalciner**
  \[
  \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
  \]
- **Fuel**
- **Rotary kiln**
  \[
  \text{1350°C}
  \]
- **Cooler**
- **Clinker**
- **Additives**
- **Mill**
- **Fuel**
- **Cement**
Rotary Kilns

Figure 2-7: Long Wet Rotary Kiln (Adapted from CEMBUREAU, 1999)
Pre-Calciners
Pre-combustion Capture

- Not a good option for cement plants
- Almost two thirds of the CO2 emissions are from limestone calcination
- Pre-combustion capture would only capture the fuel-derived CO2
- Not evaluated in IEA GHG’s study
Post-Combustion Capture at a Cement Plant

- **Air**
- **Fuel**
- **Raw meal**
- **Clinker**

Cement plant

- **24% CO₂**
- **ESP, SCR, FGD**

CHP plant

- **Coal**
- **Steam**
- **Power**

Solvent scrubbing

- **CO₂-to-reduced flue gas**

Solvent stripping

- **CO₂-compression**

CO₂ to storage
Post Combustion Capture in Cement Kiln
(Picture Courtesy of ECRA)

Figure 1. General arrangement of post-combustion CO₂ capture in a cement plant. The full animation can be seen at www.ecra-online.org.
Post-combustion Capture

- Kilns are sited on/near quarries normally with around 50-60 years of limestone reserves

**Advantages for cement plants**
- The cement plant itself is unaffected
  - But more stringent flue gas cleaning may be needed
- Retrofit to existing plants is possible
  - Provided space is available and CO2 can be transported away from the site for storage

**Disadvantages**
- A large quantity of low pressure steam is needed for solvent stripping, requiring an on-site CHP plant
Oxy-Combustion at a Cement Plant

IEA Greenhouse Gas study was based on oxy-combustion in just the pre-calciner
Oxyfuel Combustion Capture in Cement Kiln
(Picture Courtesy of ECRA)
Oxy-combustion Capture

- **Advantages for cement plants**
  - Low oxygen consumption
    - Compared to a coal fired boiler, 1/3 of the amount of O2 is needed per tonne of CO2 captured
  - Costs are expected to be relatively low

- **Disadvantages**
  - Retrofit would be difficult
  - Oxy-firing the pre-calciner captures only about 60% of the CO2
  - For full oxy-firing, air in-leakage in mills and the kiln would have to be greatly reduced
  - Impacts of full oxy-firing on kiln chemistry etc need investigating
  - More R&D is needed
Costs of CO2 Capture

- **Costs estimated for a 1Mt/y cement plant in N-W Europe**
- **Post combustion capture**
  - €107/t of CO2 emissions avoided
  - Could be reduced to €55/t by locating a cement plant next to a power plant and using a low sulphur raw meal
  - Alternative CO2 capture solvents could significantly reduce costs
- **Oxy-combustion**
  - €40/t CO2 emissions avoided
- **Cement plants would need to be close to other CO2 sources to minimise CO2 transport costs**
  - CO2 captured is 0.5-1.0 Mt/y
  - Equivalent to about 100-200 MWe coal fired power plant
Costs – Developing Countries

- Most cement production is in developing countries
  - Almost 50% in China alone
- New cement plants are often larger in developing countries and construction costs are lower
- Sensitivity case: 3Mt/y cement plant in Asia
  - Costs of CO₂ abatement would be lower
  - e.g. €23/t for oxy-combustion
Conclusions

- $\text{CO}_2$ could be captured at cement plants
- Post-combustion capture is the lowest risk option and is well suited to retrofit but costs are relatively high
- Oxy-combustion would have similar costs to $\text{CO}_2$ capture at large power plants
- Most cement production is in developing countries
- Abatement costs would be lower in developing countries
- Imports of cement from countries without $\text{CO}_2$ abatement requirements is a concern
Cement industry research - ECRA

- Initiated in 2007
- Work package A - Oxyfuel
- Work Package B - Post Combustion Oxyfuel
- Integrated concept
- Burning process is affected
- Oxygen enrichment has been applied to cement kilns
- CO₂ from the combustion process is concentrated
- Kiln plant needs redesign, retrofitting would be difficult
- High energy consumption for oxygen production

Post-combustion
- End-of-the-pipe technology
- Commercially available in other industry sectors
- Minimal impact on existing clinker process
- Pure CO₂ stream for compression
- Retrofitting is possible, no kiln redesign required
- Very high energy consumption for solvent regeneration