CCS in the Cement Industry

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CCS in Industry Workshop
Vienna, 28th April 2014
Presentation Overview

• Overview of cement production
• Techniques to reduce CO$_2$ emissions
• CCS technologies for cement plants
• Costs of CCS at cement plants
• Barriers to use of CCS in the cement industry

• Based on a recent study
  • Commissioned by Global CCS Institute
  • Managed by IEAGHG
  • Undertaken by European Cement Research Academy (ECRA), Germany
Cement Production
IEA Cement Roadmap
Cement Production

CaCO₃ → CaO + CO₂

Mill

Flue gas

Preheaters (multiple stages)

Precalcer
c

CaCO₃ → CaO + CO₂

Raw meal (limestone etc.)

Mill and drier

Hot gas

Fuel

Cement

Additives

Mill

1350°C

Fuel

Cooler

Clinker

e.g. CaO + SiO₂ etc → calcium silicates etc

Rotary kiln

900°C
Cement Plant
**CO₂ emissions**

- **Sources of CO₂ emissions**
  - Limestone decomposition (>60%)
  - Fuel combustion
  - Imported electricity (indirect emission)

- **Techniques to reduce emissions**
  - Increased energy efficiency
    - Limited scope for improvements, e.g. 10% by 2050
  - Alternative fuels
    - Tyres, waste oil, bio-wastes etc: ‘zero carbon’ biogenic material
  - Alternative raw materials and lower cement:clinker ratio
    - Limited by material availability and product quality
  - CCS
CCS

• CCS enables deep reductions in emissions
• CO$_2$ from limestone decomposition can be avoided
  • Not possible by just using alternative energy sources
• Technologies are broadly similar to those used at power plants
  • Post combustion capture
  • Oxy-combustion
  • Pre-combustion capture
    • Not preferred: would not capture the limestone-derived CO$_2$
Post Combustion Capture

Core cement plant is unaffected

Cement plant → Flue gas cleaning → Solvent scrubbing → Solvent stripping → CO$_2$ compression

Air → Fuel → Raw meal → Clinker

Flue gas → Power

Fuel → CHP plant → Steam → CO$_2$-reduced flue gas

CO$_2$ to storage

24% CO$_2$
Full Oxy-Fuel
Oxygen to calciner and kiln, ~90% capture

Changes to the core cement production process
Partial Oxy-Fuel
Oxygen to calciner only, ~60% capture

- Raw meal
- Flue gas
- Preheater 1
- Preheater 2
- Precalculator
- Kiln
- Clinker
- Fuel
- Hot gas
- Recycled flue gas
- Purification/compression
- Air separation
- CO₂
- Vent gas
- Air
- Oxygen
Calcium Looping

- Post combustion capture: \( \text{CO}_2 + \text{CaO} \rightarrow \text{CaCO}_3 \)
- Oxy-combustion regeneration: \( \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \)
- High temperature process
- Various integration options
- Degraded sorbent can be used in the cement process
  - Degraded sorbent from power plant capture units can be used in cement plants
Cement Production Cost

Reference plant
Post combustion - NGCC CHP
Post combustion - coal CHP
Partial oxyfuel
Full oxyfuel

Cement production cost, €/t
(excluding CO2 transport and storage)

(€20/t CO2 stored increases cement cost by about €10/t for full oxyfuel case)

1Mt/y clinker (1.36Mt/y cement) plant, Europe
8% discount rate, 25 year plant life, 80% capacity factor,
Coal €3/GJ, Gas €6/GJ, electricity €80/MWh
Avoidance costs 50% lower in China and Middle East
Cement Plant Capture R&D

• Norcem, Brevik, Norway
  • Test centre for small scale and pilot trials at a cement plant (2013-17)
    o Aker Solutions: amine scrubbing, mobile test unit
    o RTI: Dry adsorption, small scale trial
    o KEMA, Yodfat, NTNU: Membranes, small scale trial
    o Alstom: Calcium looping de-risking study

• ITRI/Taiwan Cement Corp.
  • 1t/h CO₂ calcium looping unit, commissioned 2013

• Skyonic Corp, Texas
  • 83 kt/y CO₂ plant at a cement plant, under construction
  • “Sky Mine” post combustion process
  • NaOH + flue gas CO₂ → sodium bicarbonate
Cement Plant Capture R&D

- Oxyfuel
  - Still at the basic research and laboratory testing stage
  - No pilot plants initiated or planned
  - ECRA is preparing a concept study for an oxyfuel pilot cement kiln
Stakeholder Survey

- Survey of the cement industry
  - Mainly cement producers, also plant manufacturers, researchers etc
  - Mainly international businesses
  - Mainly European, also N. America, Asia, Middle East
- Most respondents think CCS is relevant to them and are aware of research projects
- More than half would be willing to contribute to CCS research
- Only a third willing to contribute to pilot and demonstration projects due to high cost
Barriers to CCS

- Lack of specific funding for CCS research and demonstration in the cement industry
- Currently CCS would impair the competitiveness of cement plants
- High risk of import of cement from countries with lower abatement costs: carbon leakage
- Lack of adequate legal framework for CO$_2$ storage in some countries
Conclusions

• Established techniques can reduce cement plant emissions but scope for further reductions is limited
• CCS for the cement industry is at an early state of development
• Post combustion solvent scrubbing has potential for shorter timescale applications
• Oxy-fuel has potentially lower cost in the longer term
• Cement industry thinks CCS is relevant, they are aware of R&D but there is low willingness to contribute to pilot/demonstration plants
• Most cement production is in developing countries
• Impact on competitiveness and under-developed legal frameworks are barriers to use of CCS
Thank you, any Questions?