CCS PROJECT
IN THE CEMENT INDUSTRY

1. ECRA CCS STUDY
2. NORCEM CCS PROJECT
3. CIUDEN PROJECT

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The ECRA CCS Project
Outline

- CO₂ Reduction Scenarios and Roadmaps towards CCS
- ECRA CCS Project
- Oxy-fuel Technology
- Post-Combustion / Chemical Absorption Technology
- Summary and Outlook
IEA roadmap for the cement industry

BLUE MAP-scenario: max 1.6 Gt/a in 2050

mitigation potential
- efficiency
- RDF
- clinker ration
- CCS

source: IEA CCS Roadmap, 2009
IEA CCS Technology Roadmap

- 20–30 full-scale demonstration projects in the power sector have to be launched in the next years if CCS shall be commercial by 2030.

- In addition to the power sector, 10–20 full-scale demonstration projects for CO₂ capture in industrial processes should be operational by 2025.

- CCS investments will only occur if there are suitable financial incentives and/or regulatory constraints.

- 2050: 50 % of all cement plants in Europe, North America, Australia, East Asia are applying CCS, 20 % in India, China!
European projects on CCS in the cement industry

**ECRA phase III CCS study**
- With participants from cement industry, equipment suppliers, others
- First two reports published in 2007 and 2009

**CIUDEN / Oficemen**
- Objective to become European centre of CCS
- Started on power sector, now expanding view to other sectors including cement sector

**Norcem CCS project, Brevik**
- Small scale test rig for CCS application for post combustion
ECRA CCS Project: Objectives

- Investigations regarding the technical and economical feasibility of CCS technologies
- Sustainability aspect of CCS technologies shall be implicated
- CO$_2$ transport and storage are not subject of the research project
- Joint (European) research activities to meet the huge challenge of significant CO$_2$ reduction
- Strong interrelation to CSI, CEMBUREAU, PCA, etc. to communicate the cement industry’s activities on CCS and CO$_2$ reduction
Research Agenda – ECRA CCS Project

ECRA started the CCS project 2007, its third phase is commenced.

- **Phase I**: Literature Study (January - June 2007) ✓
- **Phase II**: Study about Oxy-fuel and Post-Combustion Technology (summer 2007 – autumn 2009) ✓
- **Phase III**: Laboratory-scale / small-scale research activities (spring 2010 – winter 2011)
- **Phase IV**: Pilot-scale research activities (time-frame: 2-3 years)
- **Phase V**: Demonstration plant (time-frame: 3-5 years)
## ECRA CCS Project: Research Consortium Phase III

<table>
<thead>
<tr>
<th>Category</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Producers:</td>
<td>Buzzi Unicem, CRH, Cementos Molins, Cemex, Cimpor, HeidelbergCement, Holcim, Italcementi, Lafarge, Phoenix, Schwenk, Secil, Spenner, Titan, Vicat, PZW Wittekind</td>
</tr>
<tr>
<td>Cement Organizations:</td>
<td>CEMBUREAU, Cemsuisse, CSI, VDZ</td>
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<tr>
<td>Equipment Suppliers:</td>
<td>Polysius, FLSmidth, KHD</td>
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<tr>
<td>Gas Producers:</td>
<td>Praxair</td>
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**CCS in Cement Industry – Two Options**

**Oxy-fuel**
- integrated concept
- flue gas recirculation

**Post-combustion capture**
- end-of-pipe technique
- chemical flue gas scrubbing

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**Air separation** → **N₂**

**Kiln** → **CO₂, H₂O** → **Compression** → **CO₂**

**air** → **Kiln** → **Absorption** → **N₂, O₂** → **Compression** → **CO₂**
Within the framework of phase III, the research work is organised in individual work packages. Cooperation with external project partners is envisaged.

**Work packages oxy-fuel technologies:**
Process simulation, burner design, investigations on clinker quality, optimization of sealings and refractories, flue gas conditioning, layout of an oxy-fuel cement plant

**Work packages chemical absorption technologies:**
Modelling of absorption processes, amine degradation studies, small-scale trials with cement flue gases, FEED study
Oxy-fuel – Research progress

Investigations on clinker quality: Study executed by the Research Institute

- Identification of most important parameters on clinker susceptibility to CO₂-atmosphere

General Flue Gas Conditioning: Study executed by Praxair

- Development of a plant for compression and purification of CO₂ rich flue gas from an oxy-fuel cement kiln
- Including process and equipment engineering, plant design and capital costs estimation

Optimization of sealings: Study executed by Aixergée

- Identification and classification of leakage locations
- Development and evaluation of three solutions based on different technical approaches
Oxy-fuel – Impact on Clinker Burning Process

Issues arising from oxy-fuel application investigated in phase II:

- Influences of an increasing CO₂ partial pressure on material conversion
- Influences on kiln operation due to changed burning atmosphere
- Integration of chemical plant components
- Modifications of the plant technology
- Maximum capture rate
- Energy demand and costs

Areas requiring further research:

Influences of an increasing CO₂ partial pressure on

- Process modelling
- Laboratory tests
- Optimization of seals
- Waste heat utilization
- Burner design
- CO₂-purification facility
- Clinker Cooler Design
- Refractory lining
Oxy-fuel – Cost Estimation

Investment costs

New installation:

2030: 330 - 360 Mio €

2050: 270 - 295 Mio €

Remark: Costs for demonstration plant in 2020 will be significantly higher

Operational costs

Total cost increase of about 40 %

Additional costs per ton of avoided CO$_2$: 33 - 36 €/t CO$_2$
Post-combustion – Research progress

- Modelling of the CO$_2$ absorption and desorption. Inclusion of the model into the Research Institute’s cement plant simulation
- Investigating the solvent degradation process with cement-specific flue gas constituents
- Plan of a small-scale test site and application for funding
Post-combustion – Small-scale trials

- Location: Brevik, Norway
- Concept: Small-scale unit for testing different absorption techniques
- Dimension: approx 1 t/h
- Partial funding granted through Norwegian government
- Open to participation from others
- Vision: Operate the first small-scale post-combustion capture facility in cement industry by 2013/14
Post-combustion – Impact on the Clinker Process

Issues arising from post-combustion application investigated in phase II:

- Resulting energy and mass flows
- Influences on kiln operation due to additional equipment
- Energy efficient integration into the existing process
- Absorbent degradation
- Modifications of the plant technology
- Maximum capture rate
- Energy demand and Costs

Areas requiring further research:

- Process modelling
- Degradation experiments
- Energy integration
- Waste heat utilization
- Small-scale tests
- Alternative heat sources
Post-combustion Technology – Cost Estimation

**Investment costs**

Retrofit:

- 2030: 100-300 Mio €
- 2050: 80-240 Mio €

Remark: The energy/CO2 penalty has a strong influence of the overall costs

**Operational costs**

- 2030: up to 50 € per ton of CO₂
- 2050: up to 40 € per ton of CO₂

The reboiler for the solvent stripper is the most important expense factor.
Summary & Outlook

- Today, CO₂ capture technologies are not technically available for the cement industry.
- Oxy-fuel combustion is state-of-the-art in a few other industry sectors and seems to be promising for new kilns.
- Post-combustion capture is state-of-the-art in other industrial sectors, but on relatively small scale.
- From a today's point of view CCS is by far too expensive for the cement industry.
- ECRA CCS project is organized in five phases – from literature studies to a potential demonstration project.
- ECRA research project shall enable the cement industry to give scientifically based reliable answers to political requirements in the future.
CCS CIUDEN-OFICEMEN PROJECT
WHAT IS CIUDEN?

CIUDEN: Fundación Ciudad de la Energía
An initiative of the Spanish Administration
WHAT IS CIUDEN?

- A public law body
- Conceived for collaborative research
- Oriented to technological development
- A non-profit organisation
- Open for international cooperation
WHAT IS CIUDEN?

Compostilla P.S. ENDESA

CIUDEN’s Capture TDP
WHAT IS CIUDEN?

Ciuden is designing, constructing and will operate Technology Development Plants (TDPs)
Budget: 180 Mill.€

**Capture**
- To validate close-to-market and emerging technologies for application at commercial scale

**Transport**
- To obtain technical criteria for design, management and safe operation of CO$_2$ pipelines through long-term runs

**Storage**
- To develop technologies and processes for injection and monitoring in saline aquifers to support industrial-scale activities
OFICEMEN/CIUDEN AGREEMENT

2-2-2010 OFICEMEN signed a global program of collaboration with CIUDEN.

Areas that the agreement will be focus are:

- Application of technologies of oxycombustion partial in the process of cement production
- CO$_2$ Capture with special attention to the applicability of the technologies to the cement industry
- Contribution of CO$_2$ capture, transport and storage to the fulfillment of reduction of CO$_2$ emissions.