



# Challenges to the Deployment of CCS in the Energy Intensive Industries

(Part 2: Cement Industry Sector)

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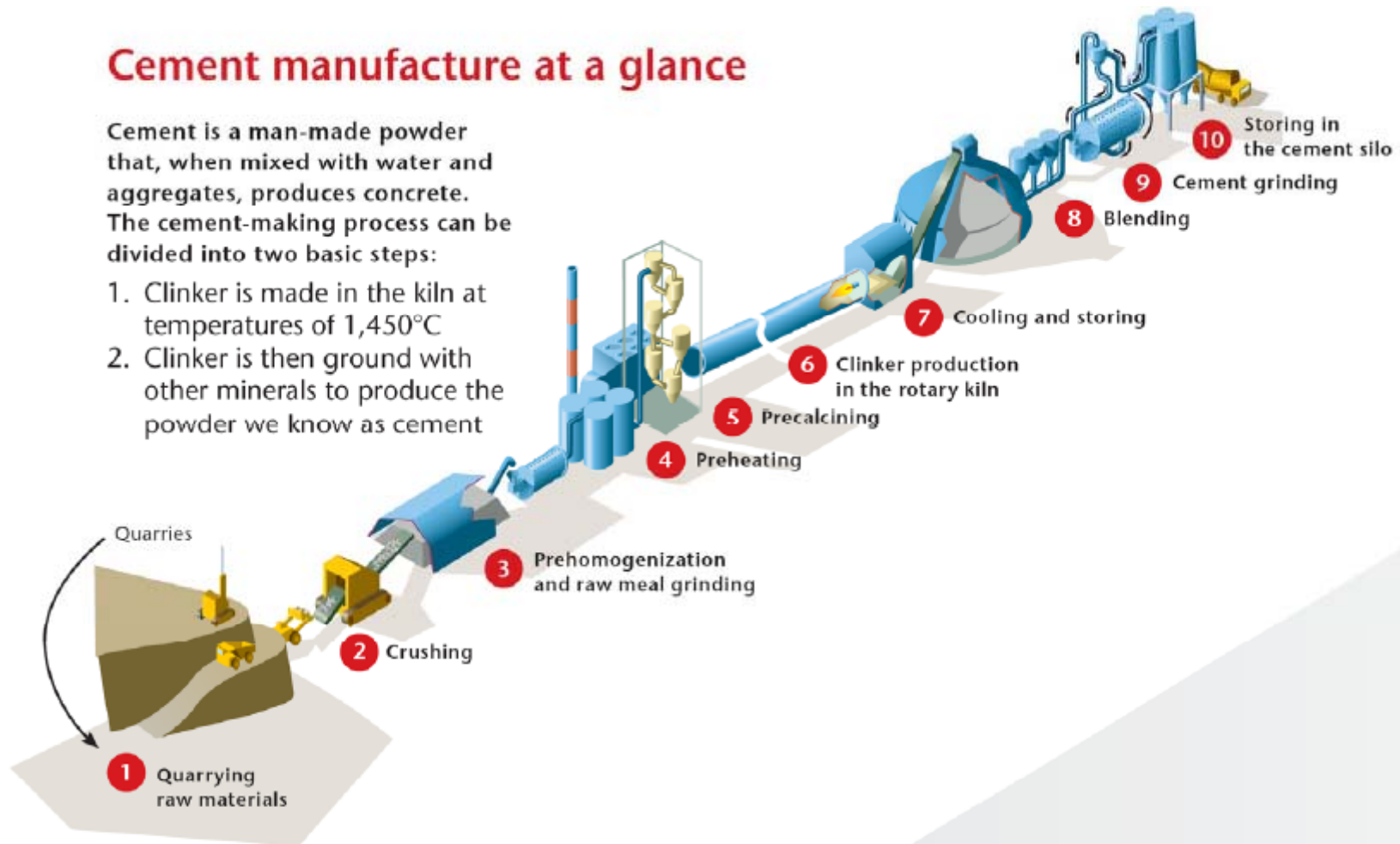
IEA Greenhouse Gas R&D Programme  
Cheltenham, UK

**IEA – MOST Joint Workshop**  
**CCS Opportunities in Energy Intensive Industry**  
**16<sup>th</sup> October 2012**

## 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:

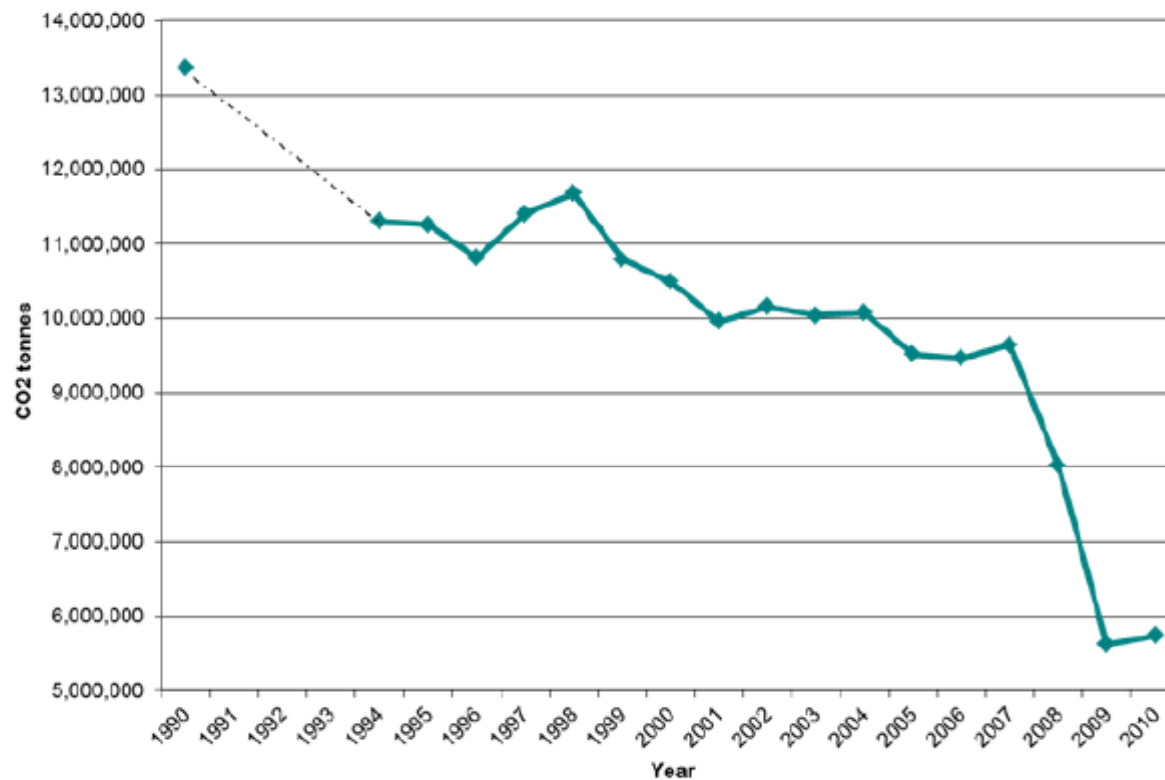
1. Clinker is made in the kiln at temperatures of 1,450°C
2. Clinker is then ground with other minerals to produce the powder we know as cement



Source: WBCSD Cement Technology Roadmap 2009

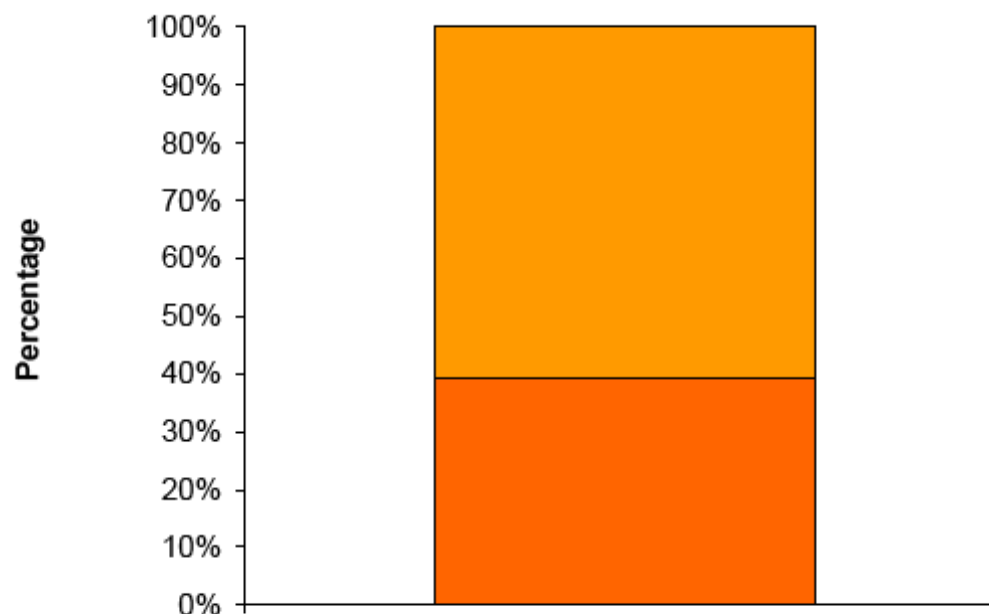
## Direct CO<sub>2</sub> Emissions Reduction - UK cement

MPA Cement <sup>(4)</sup> Reduction in Absolute Carbon Dioxide Emissions  
1990 to 2010



# Direct CO<sub>2</sub> emissions - clinker

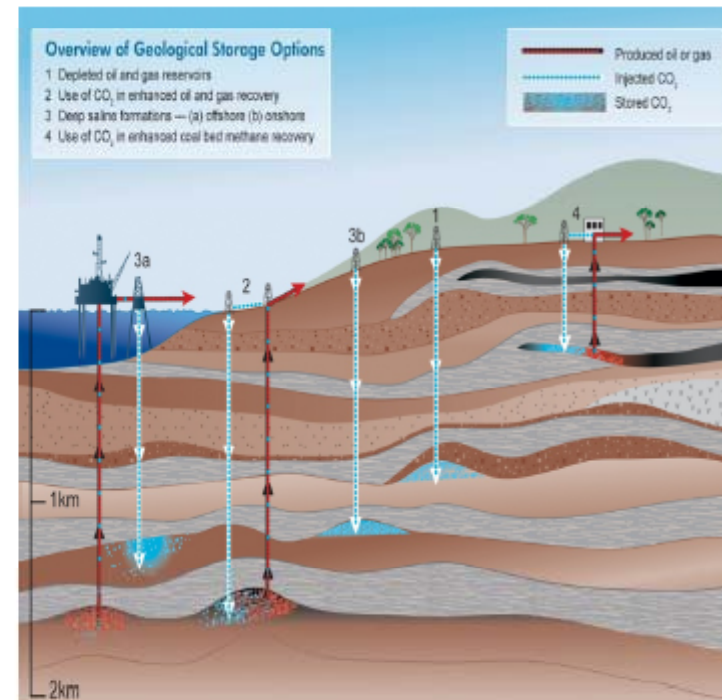
Carbon Dioxide Emission from Clinker Production



<span style="color: #FFA500;">■</span> Calcination (Process) CO <sub>2</sub> %	<b>61</b>
<span style="color: #FF8C00;">■</span> Combustion (Fuel) CO <sub>2</sub> %	<b>39</b>

## Cement industry research

- Cement emission ~25% CO<sub>2</sub>
- 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



Source: IEA GHG programme



# CO<sub>2</sub> CAPTURE IN THE CEMENT INDUSTRY

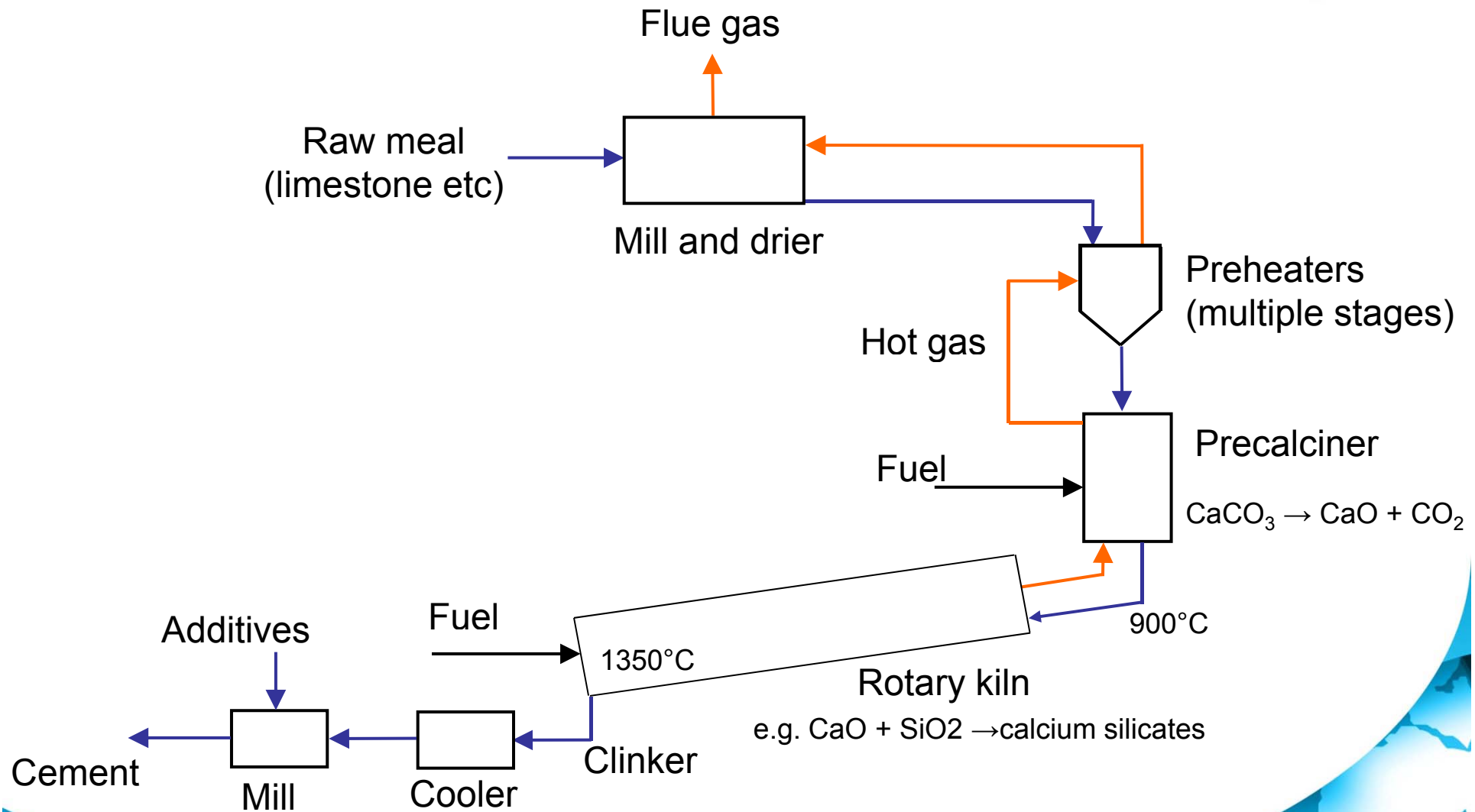
*Technical Study*

*Report Number: 2008/3*

*Date: July 2008*

*This document has been prepared for the Executive Committee of the IEA GHG Programme.  
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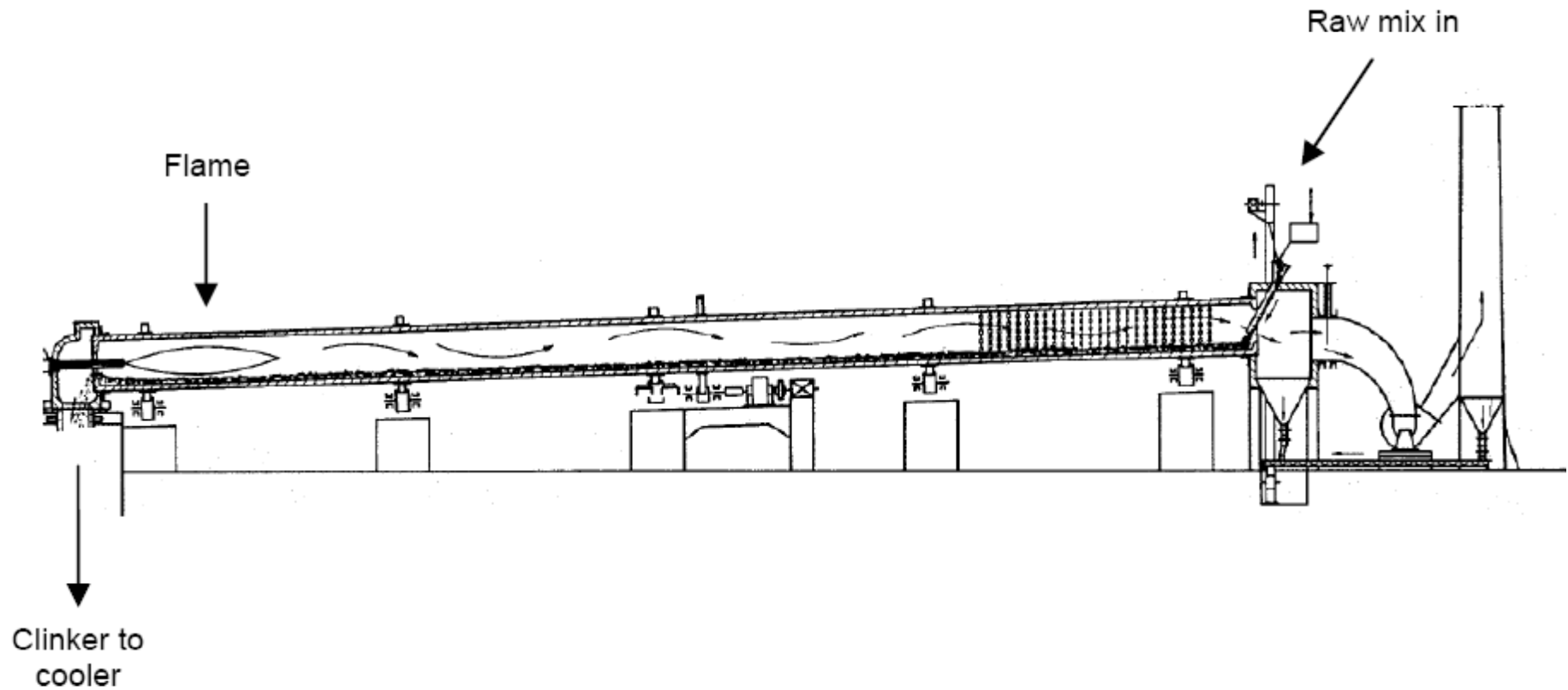
# Cement Production



# Rotary Kilns

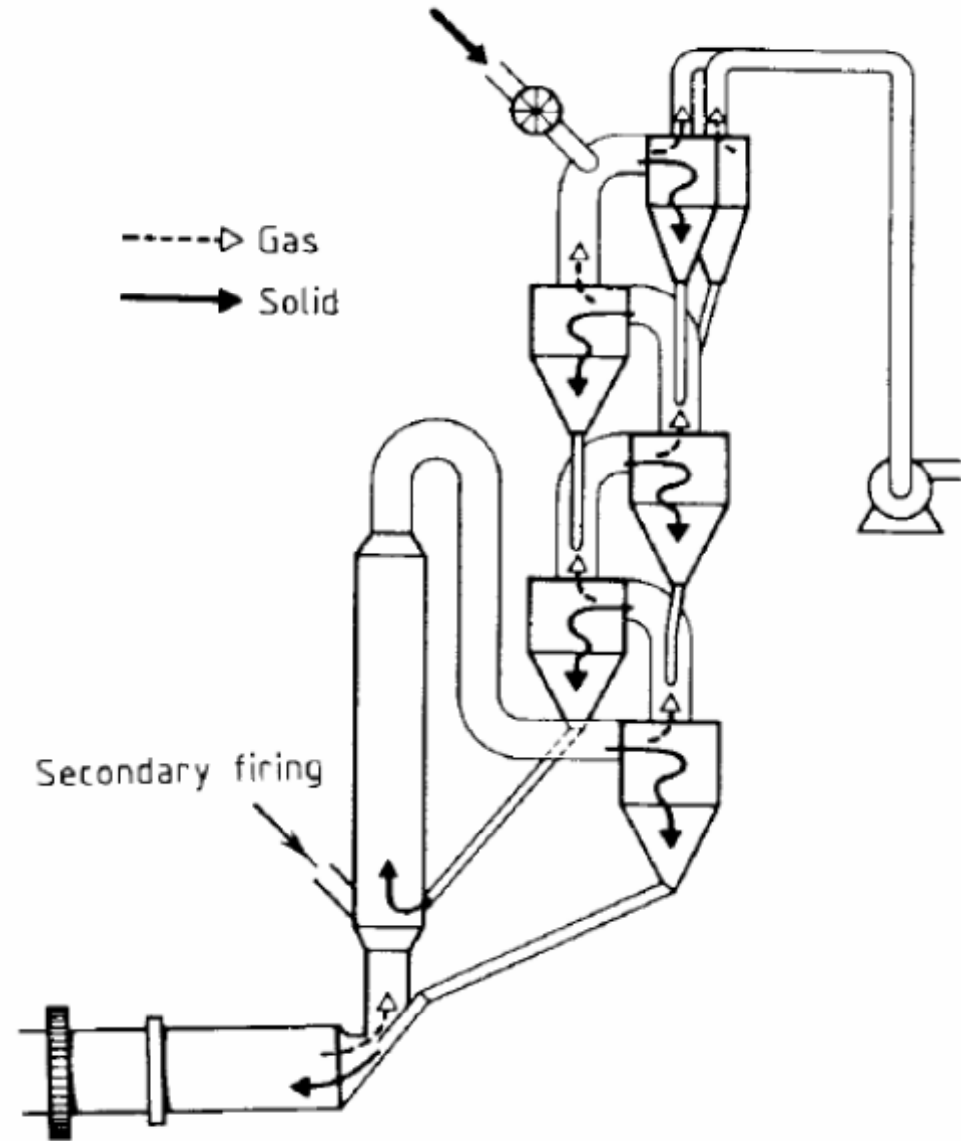
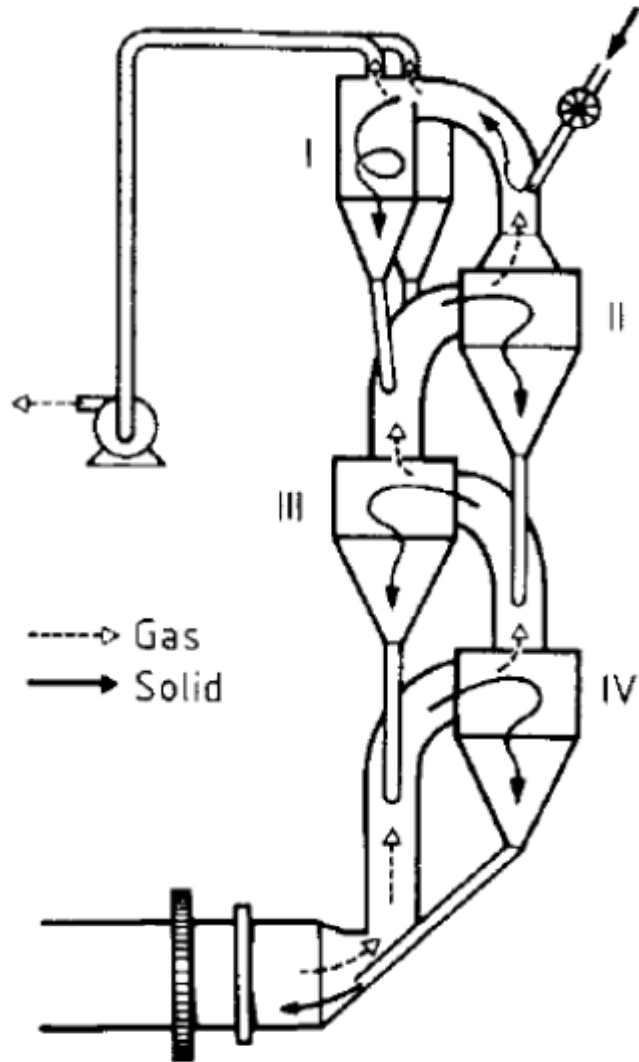


Figure 2-7: Long Wet Rotary Kiln (Adapted from CEMBUREAU, 1999)





# Pre-Calciners

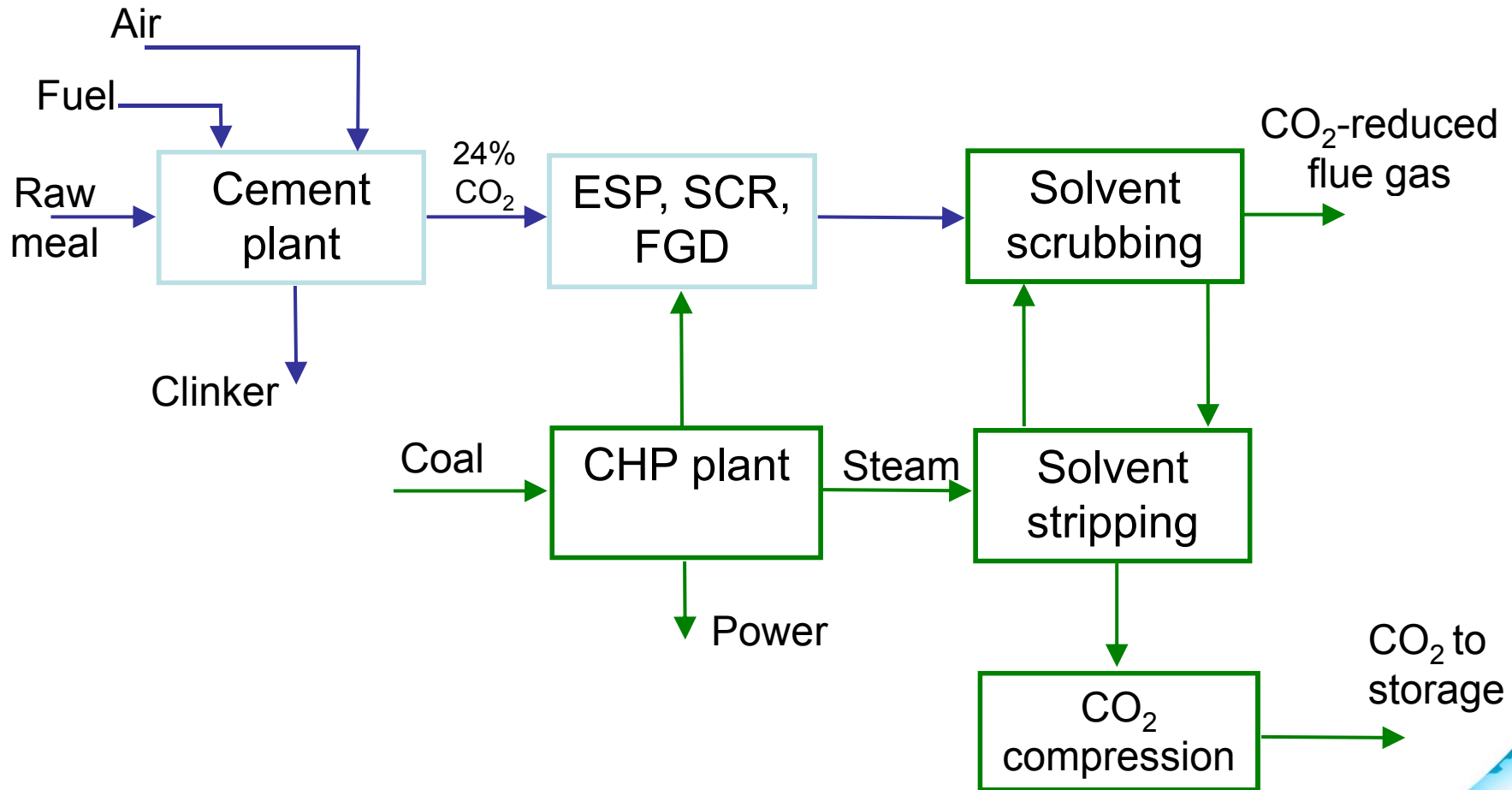


# Pre-combustion Capture



- *Not a good option for cement plants*
- *Almost two thirds of the CO<sub>2</sub> emissions are from limestone calcination*
- *Pre-combustion capture would only capture the fuel-derived CO<sub>2</sub>*
- *Not evaluated in IEA GHG's study*

# Post-Combustion Capture at a Cement Plant



# Post Combustion Capture in Cement Kiln (Picture Courtesy of ECRA)

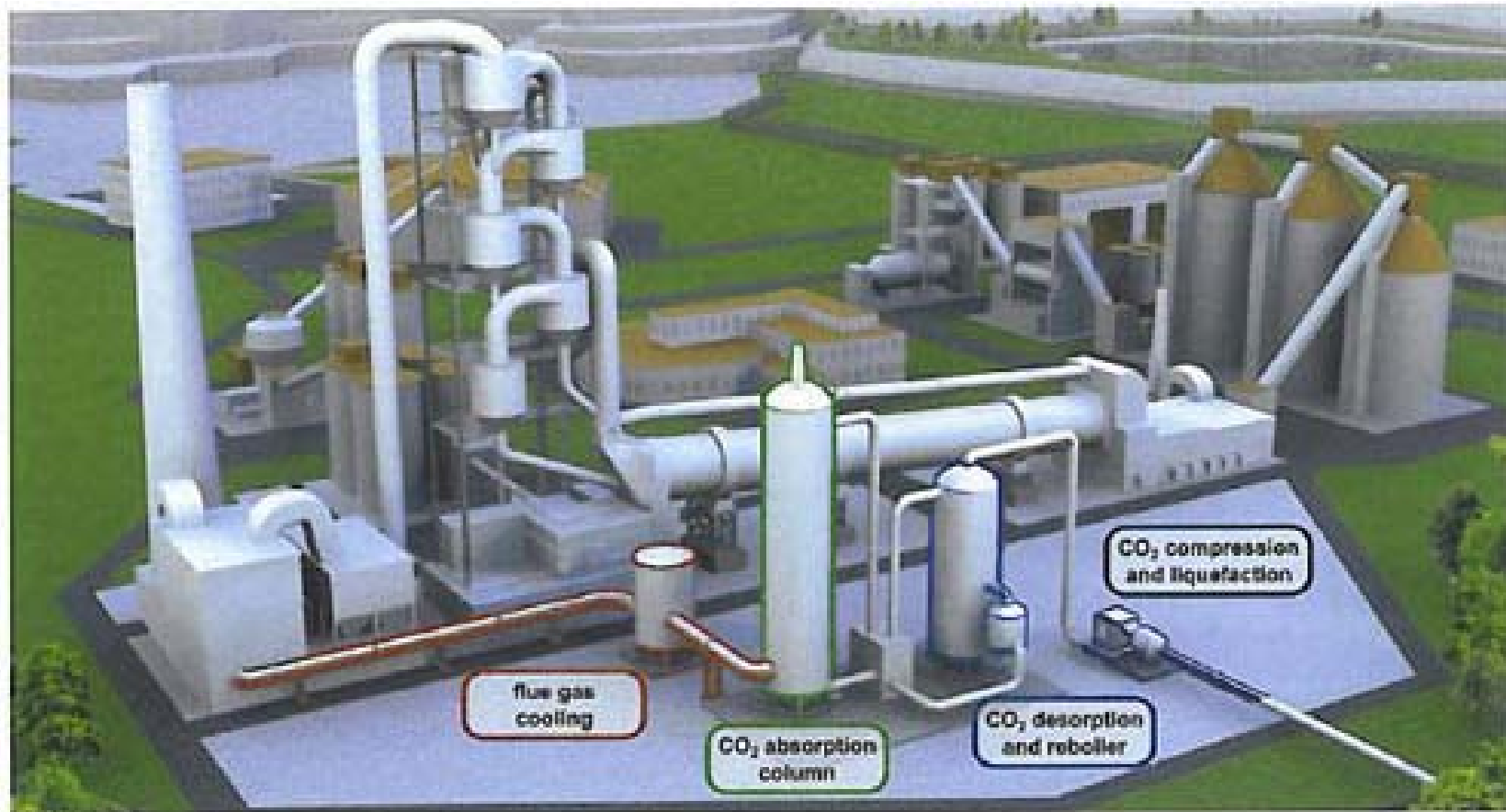


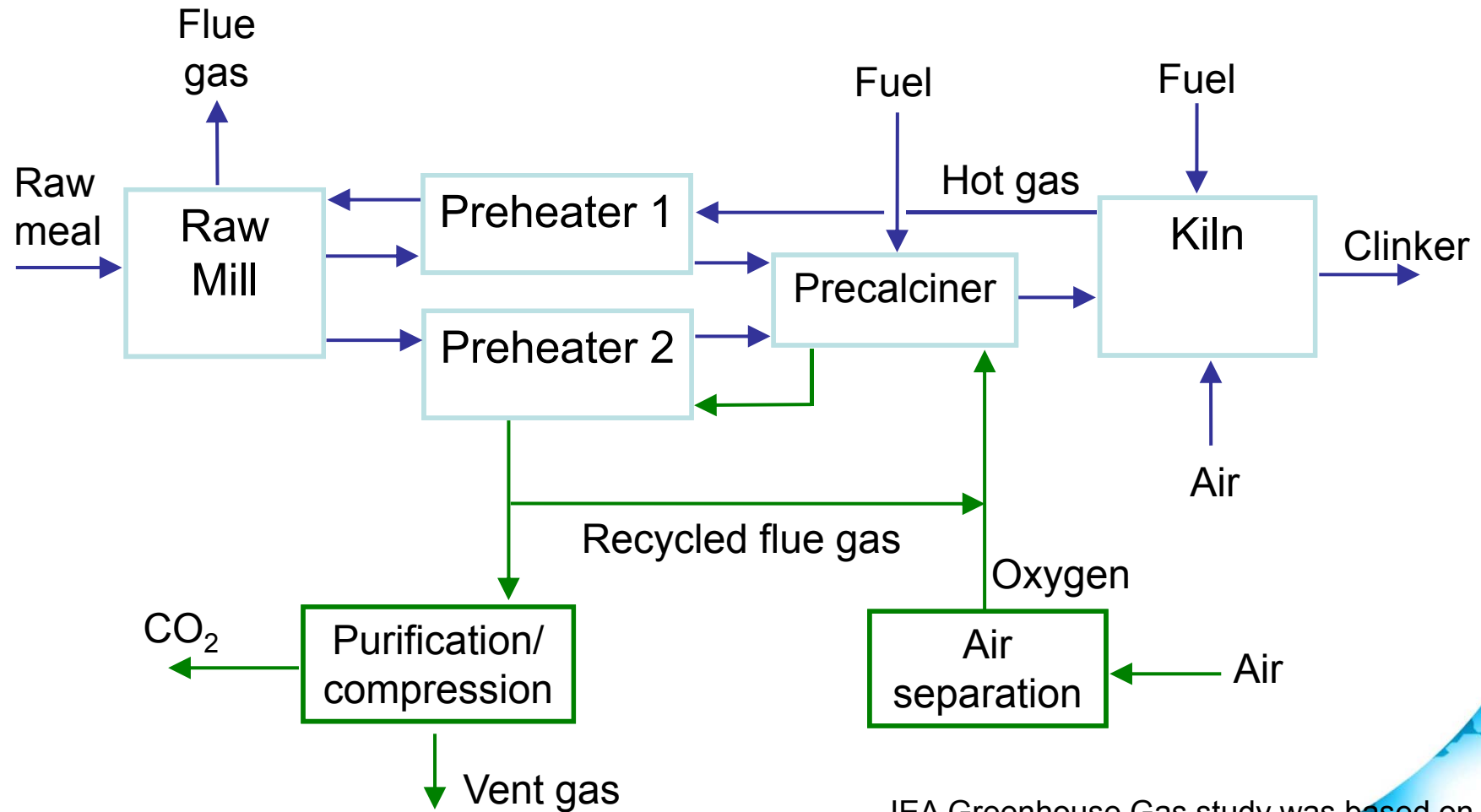
Figure 1. General arrangement of post-combustion CO<sub>2</sub> capture in a cement plant. The full animation can be seen at [www.ecra-online.org](http://www.ecra-online.org).

# 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 CO<sub>2</sub> 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)



Figure 2. The general arrangement of oxyfuel technology on a rotary cement kiln.

# Oxy-combustion Capture



- ***Advantages for cement plants***

- Low oxygen consumption
  - Compared to a coal fired boiler, 1/3 of the amount of O<sub>2</sub> is needed per tonne of CO<sub>2</sub> captured
- Costs are expected to be relatively low

- ***Disadvantages***

- Retrofit would be difficult
- Oxy-firing the pre-calciner captures only about 60% of the CO<sub>2</sub>
- 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 CO<sub>2</sub> Capture



- ***Costs estimated for a 1Mt/y cement plant in N-W Europe***
- ***Post combustion capture***
  - €107/t of CO<sub>2</sub> 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 CO<sub>2</sub> capture solvents could significantly reduce costs
- ***Oxy-combustion***
  - €40/t CO<sub>2</sub> emissions avoided
- ***Cement plants would need to be close to other CO<sub>2</sub> sources to minimise CO<sub>2</sub> transport costs***
  - CO<sub>2</sub> 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 CO<sub>2</sub> abatement would be lower
  - e.g. €23/t for oxy-combustion

# Conclusions



- *CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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
- CO<sub>2</sub> 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 CO<sub>2</sub> stream for compression
- Retrofitting is possible, no kiln redesign required
- Very high energy consumption for solvent regeneration

## ECRA CCS Project: Research Consortium Phase III

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Cement Producers: Buzzi Unicem, CRH, Cementos Molins, Cemex, Cimpor, HeidelbergCement, Holcim, Italcementi, Lafarge, Phoenix, Schwenk, Secil, Spenner, Titan, Vicat, PZW Wittekind

Cement Organizations: CEMBUREAU, Cemsuisse, CSI, VDZ

Equipment Suppliers: Polysius, FLSmidth, KHD

Gas Producers: Praxair

## **ECRA CCS Project: Work Packages Phase III**

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The research work is organised in individual work packages, in cooperation with external project partners:

### **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 – Impact on Clinker Burning Process

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

- Influences of an increasing CO<sub>2</sub> 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 CO<sub>2</sub> partial pressure on

- Process modelling
- Laboratory tests
- Optimization of seals
- Waste heat utilization
- Burner design
- CO<sub>2</sub>-purification facility
- Clinker Cooler Design
- Refractory lining

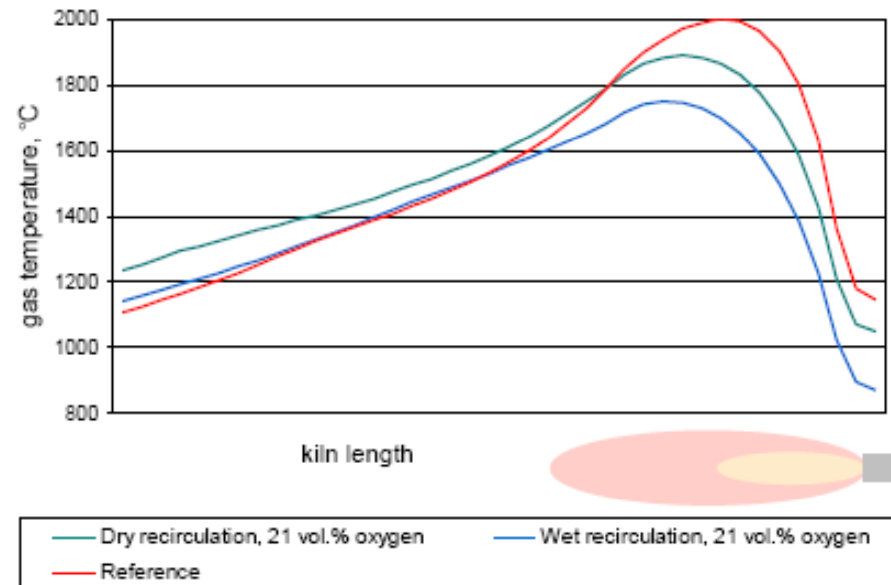
# Oxy-fuel – Process modelling

## Objectives:

- Developing oxy-fuel process model by adding further aggregates
- Comprehensive simulation study by parameter variation
- Iterative data exchange with other work packages

## Deliverables:

- Identification of limiting factors
- Optimization of operational mode
- Energetic implementation of additional plant aggregates





# 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 – Small-scale trials

- Location: Brevik, Norway
- Concept: Small-scale unit for testing different absorption techniques
- Dimension: approx 1 t/h
- Application to Norwegian government on track (September 2010)
- Open to participation from others
- Vision: Operate the first small-scale post-combustion capture facility in cement industry by 2013/14



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