



Challenges to the Deployment of CCS in the Energy Intensive Industries

(Part 2: Cement Industry Sector)

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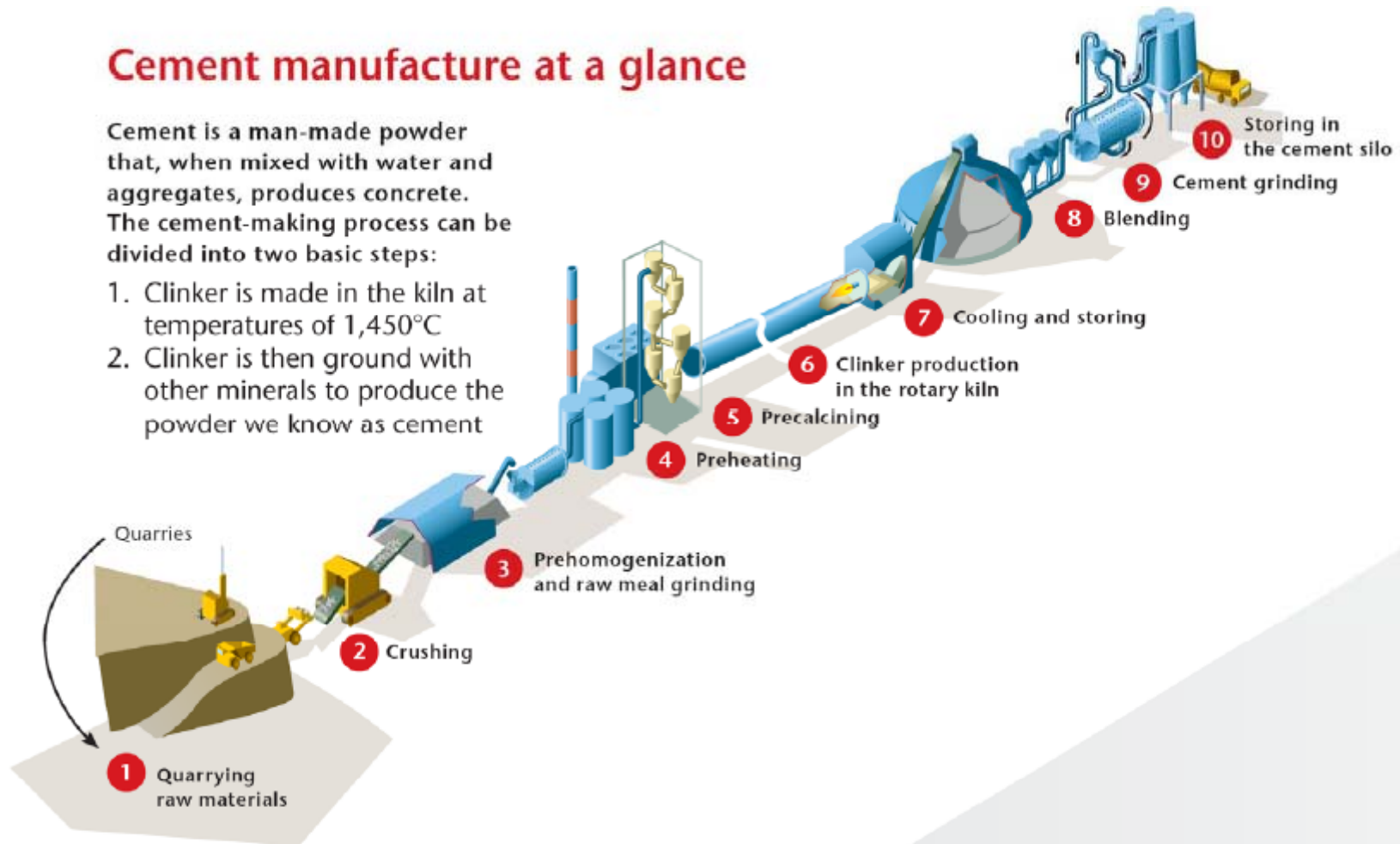
IEA Greenhouse Gas R&D Programme
Cheltenham, UK

IEA – MOST Joint Workshop
CCS Opportunities in Energy Intensive Industry
16th 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:

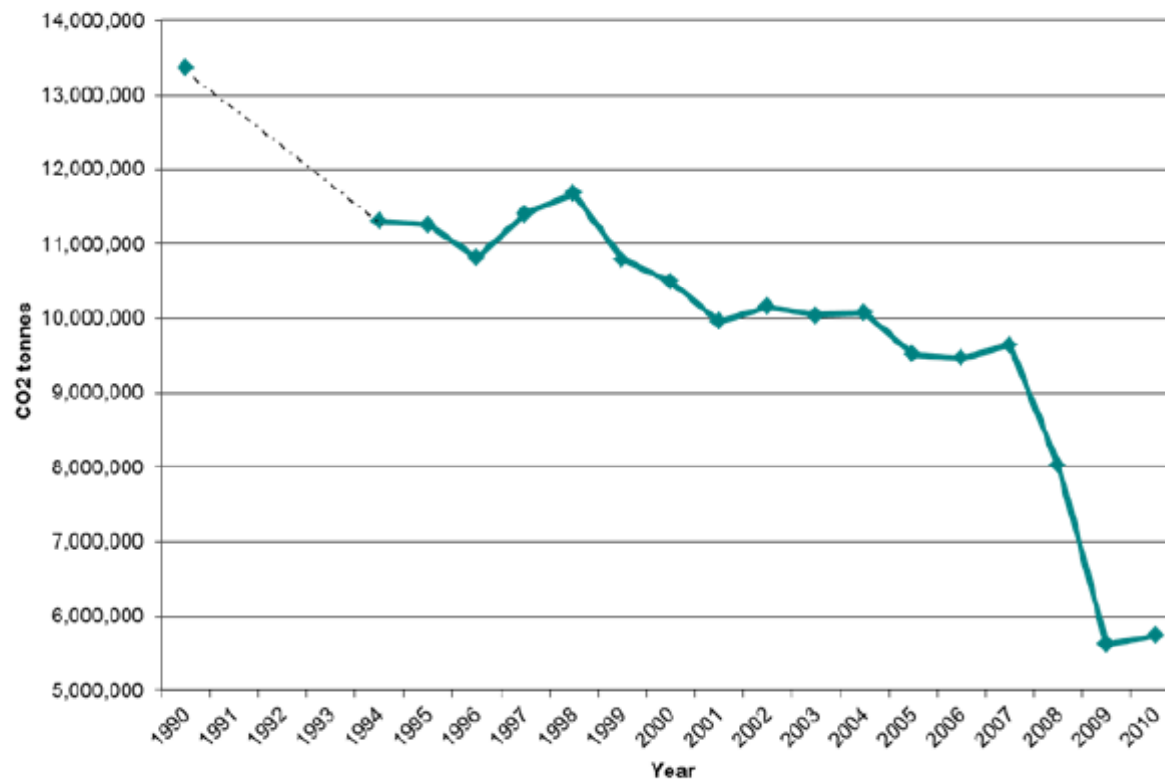
1. Clinker is made in the kiln at temperatures of 1,450°C
2. Clinker is then ground with other minerals to produce the powder we know as cement



Source: WBCSD Cement Technology Roadmap 2009

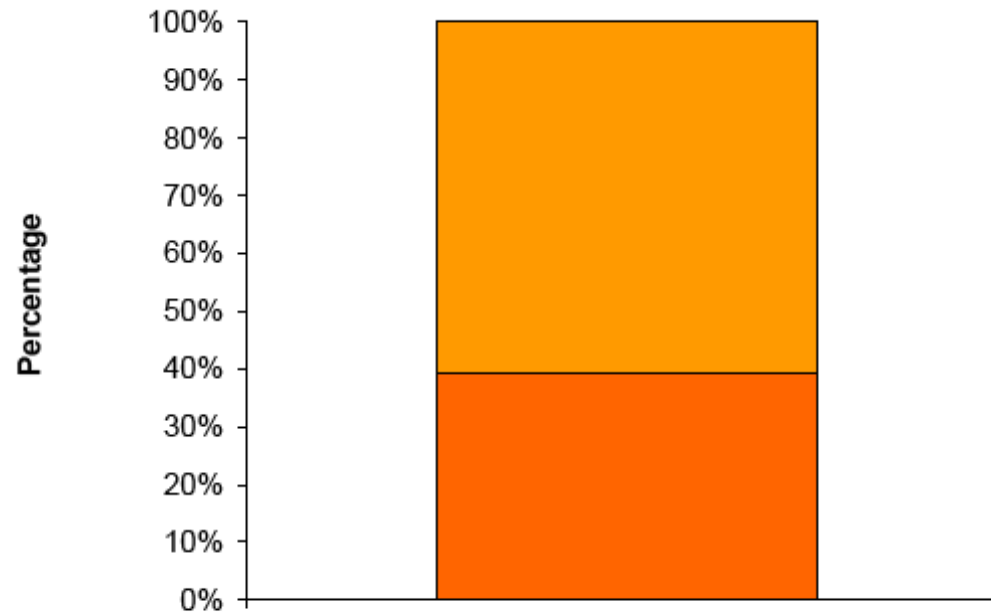
Direct CO₂ Emissions Reduction - UK cement



MPA Cement ⁽⁴⁾ Reduction in Absolute Carbon Dioxide Emissions
1990 to 2010



Direct CO₂ emissions - clinker

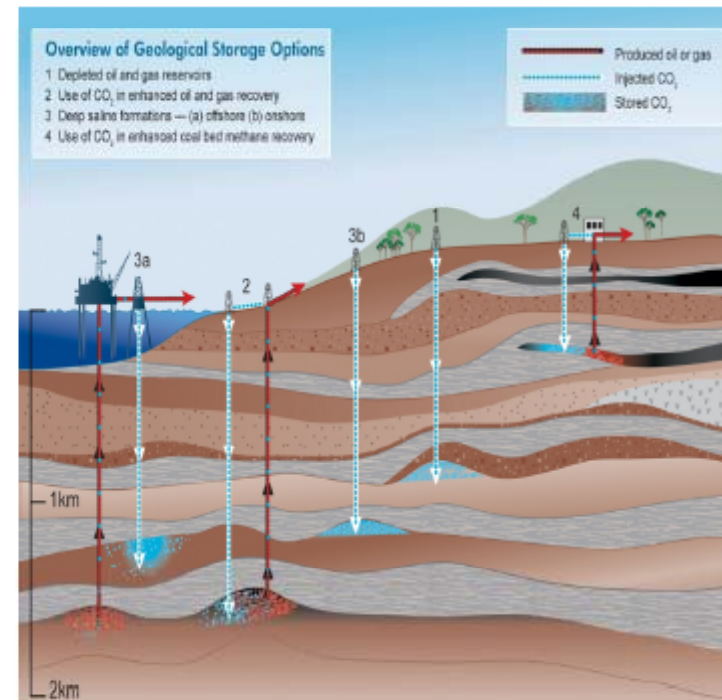
Carbon Dioxide Emission from Clinker Production



| | |
|---|-----------|
|  Calcination (Process) CO₂ % | 61 |
|  Combustion (Fuel) CO₂ % | 39 |

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



Source: IEA GHG programme



CO₂ CAPTURE IN THE CEMENT INDUSTRY

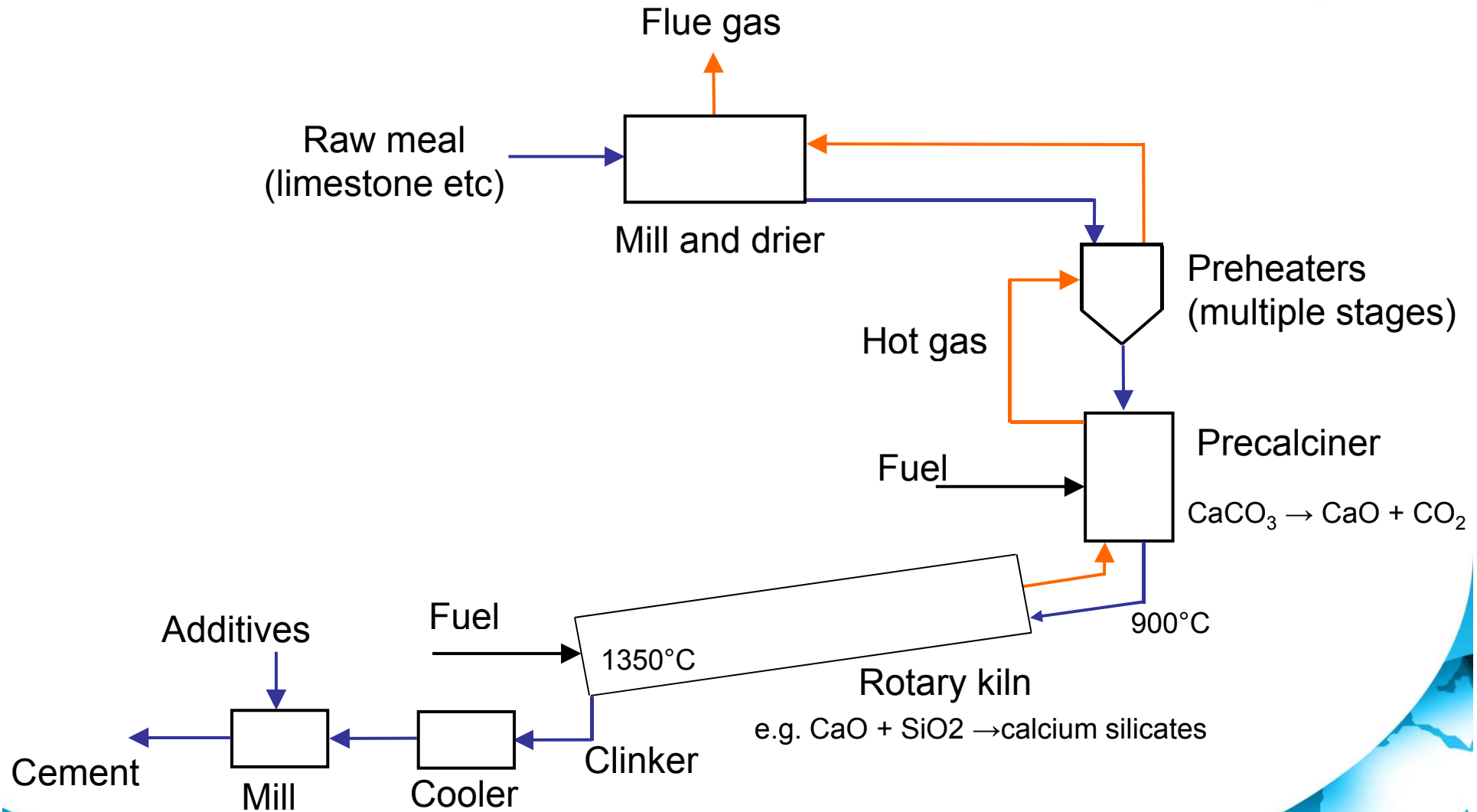
Technical Study

Report Number: 2008/3

Date: July 2008

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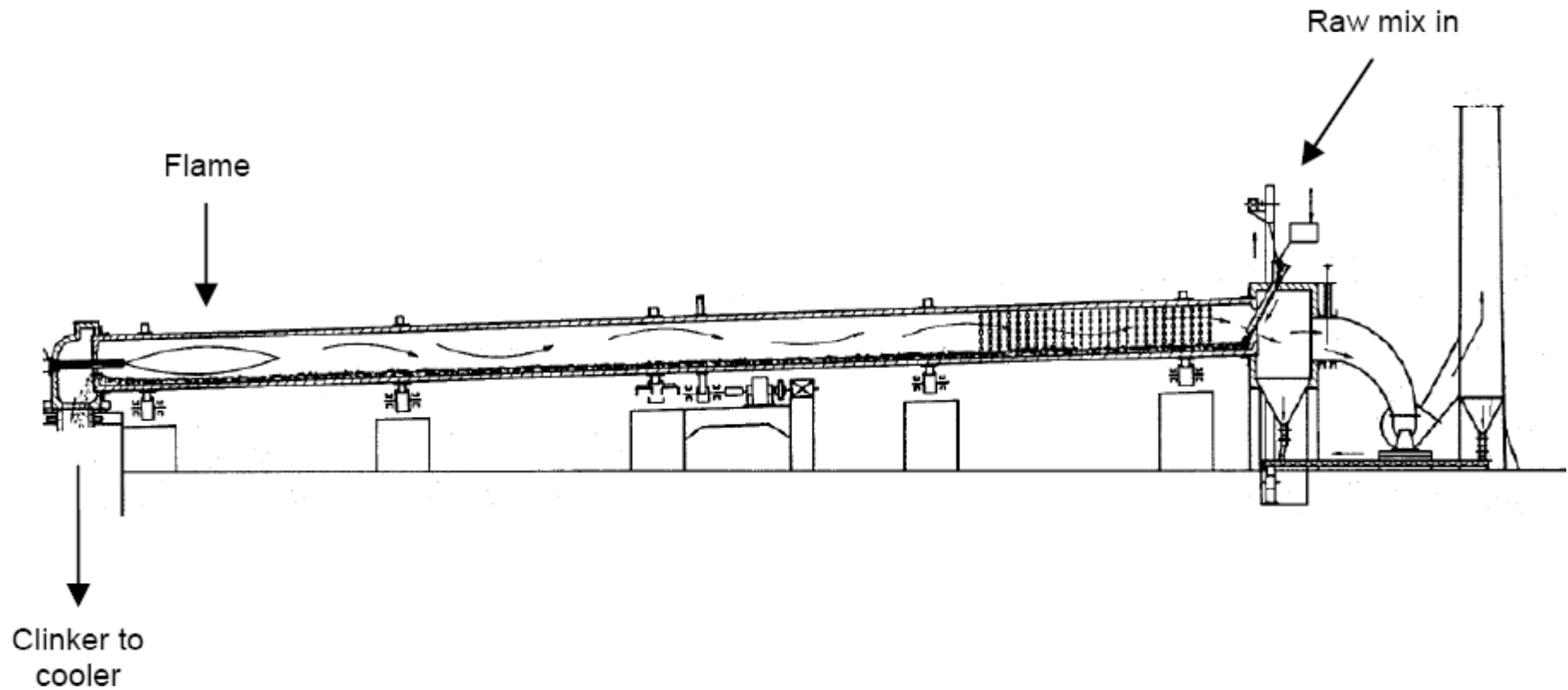
Cement Production



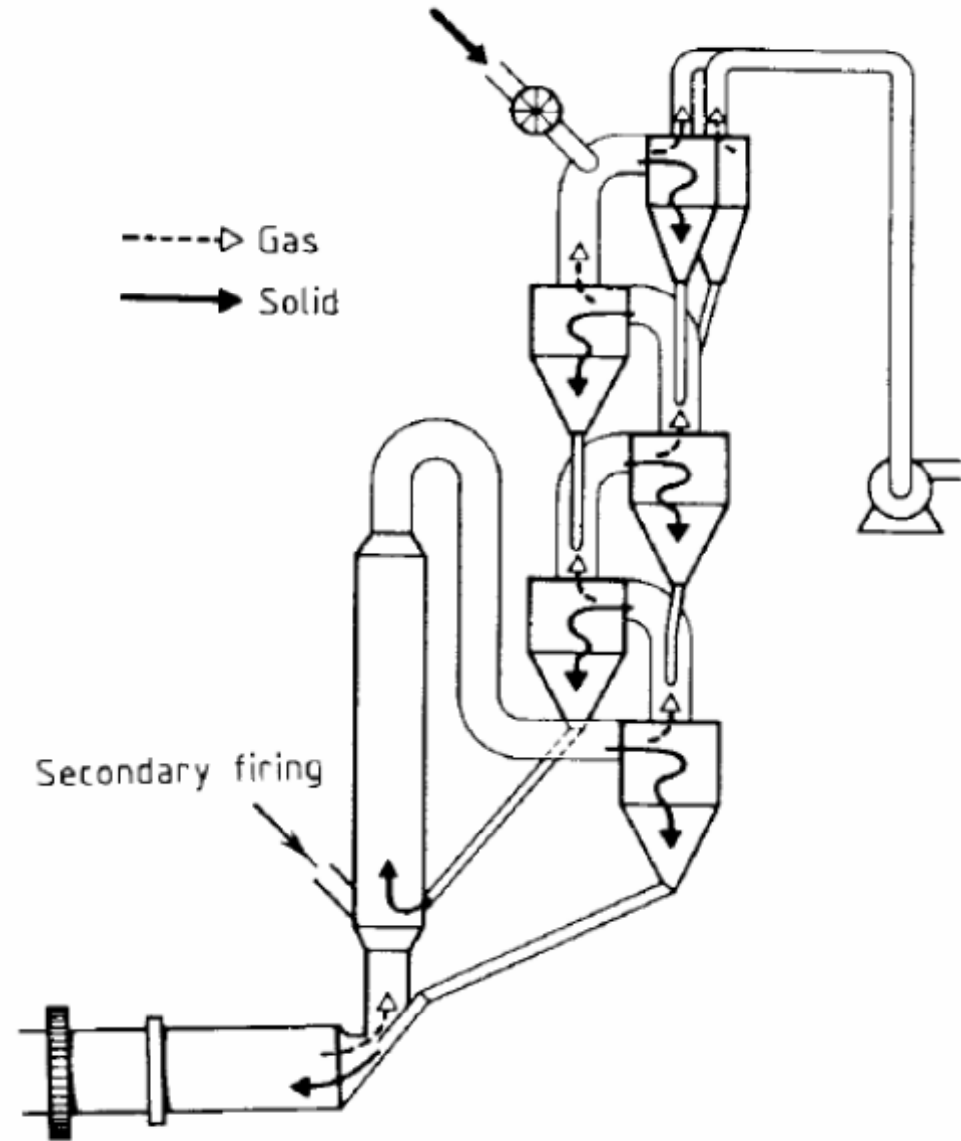
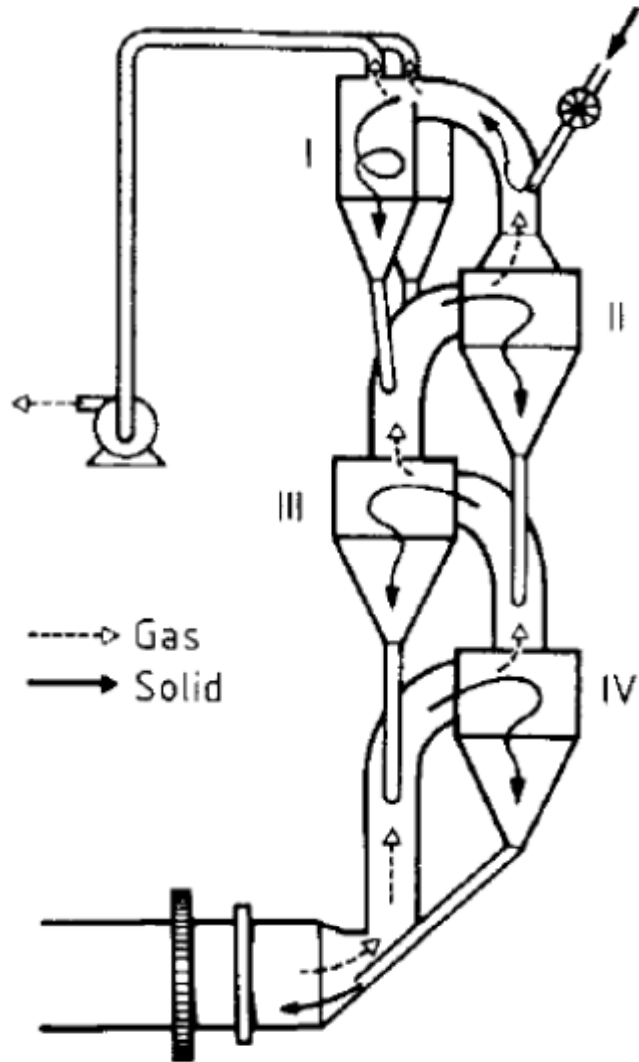
Rotary Kilns



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



Pre-Calciners

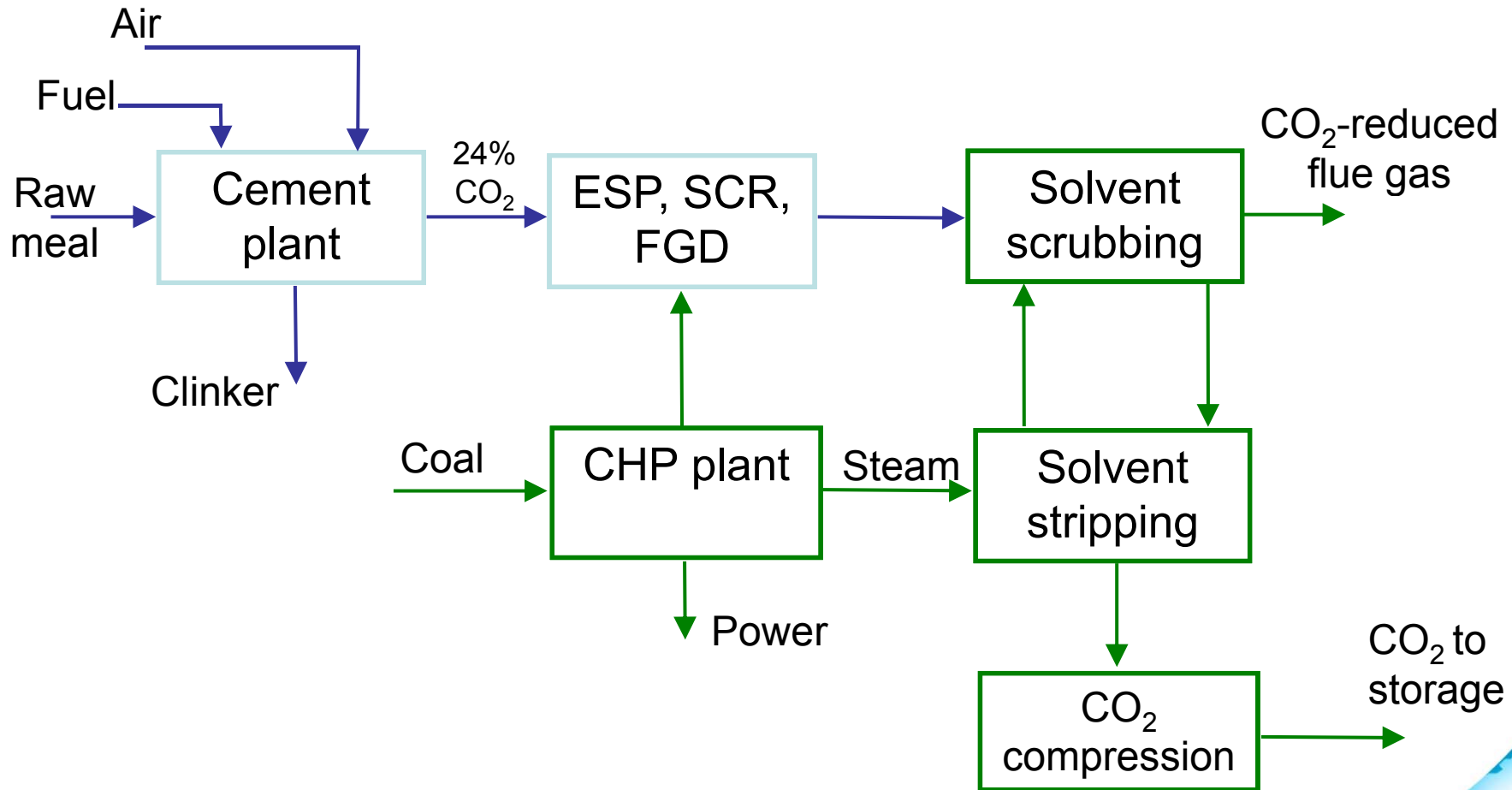


Pre-combustion Capture



- *Not a good option for cement plants*
- *Almost two thirds of the 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



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

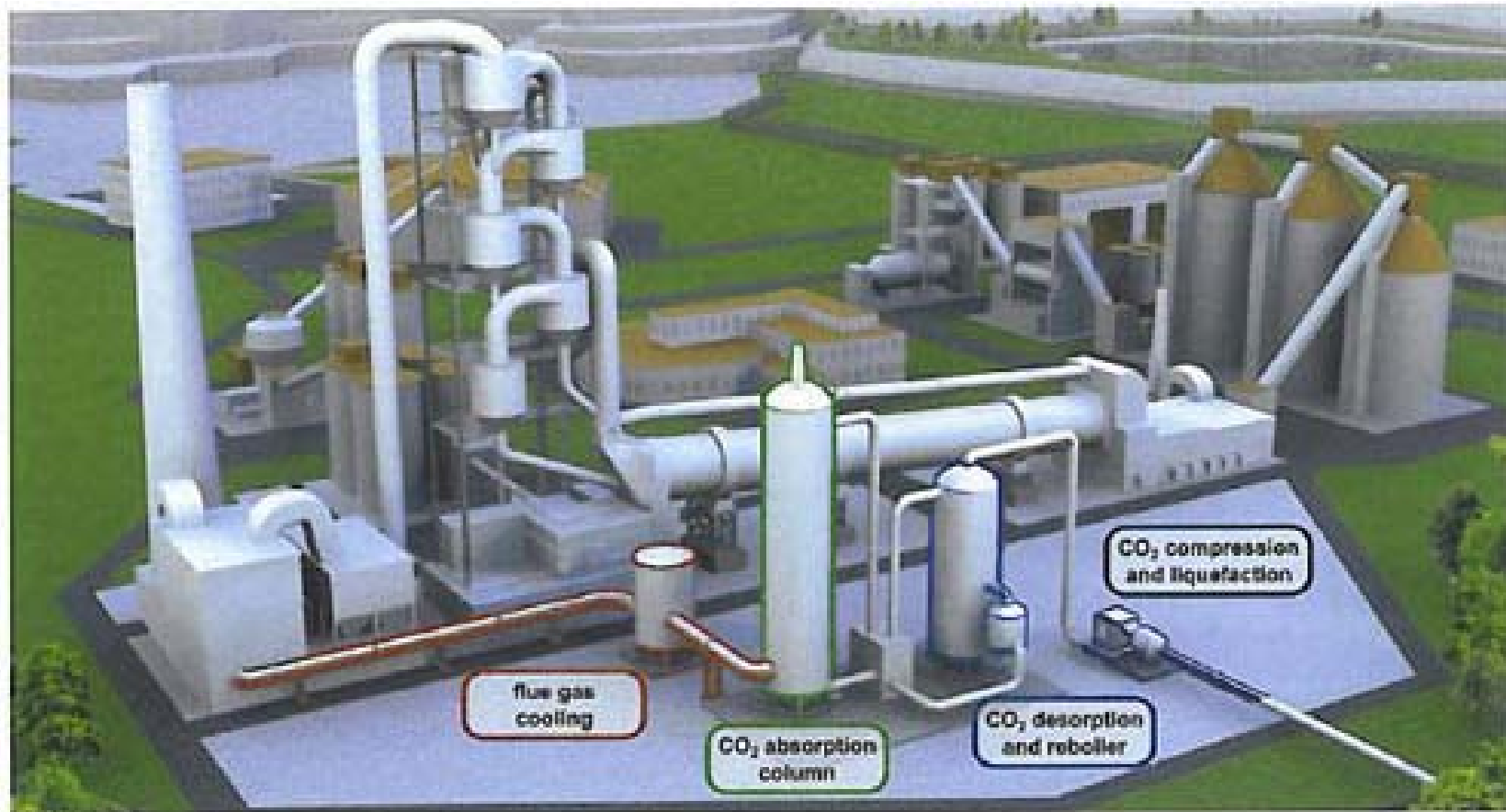


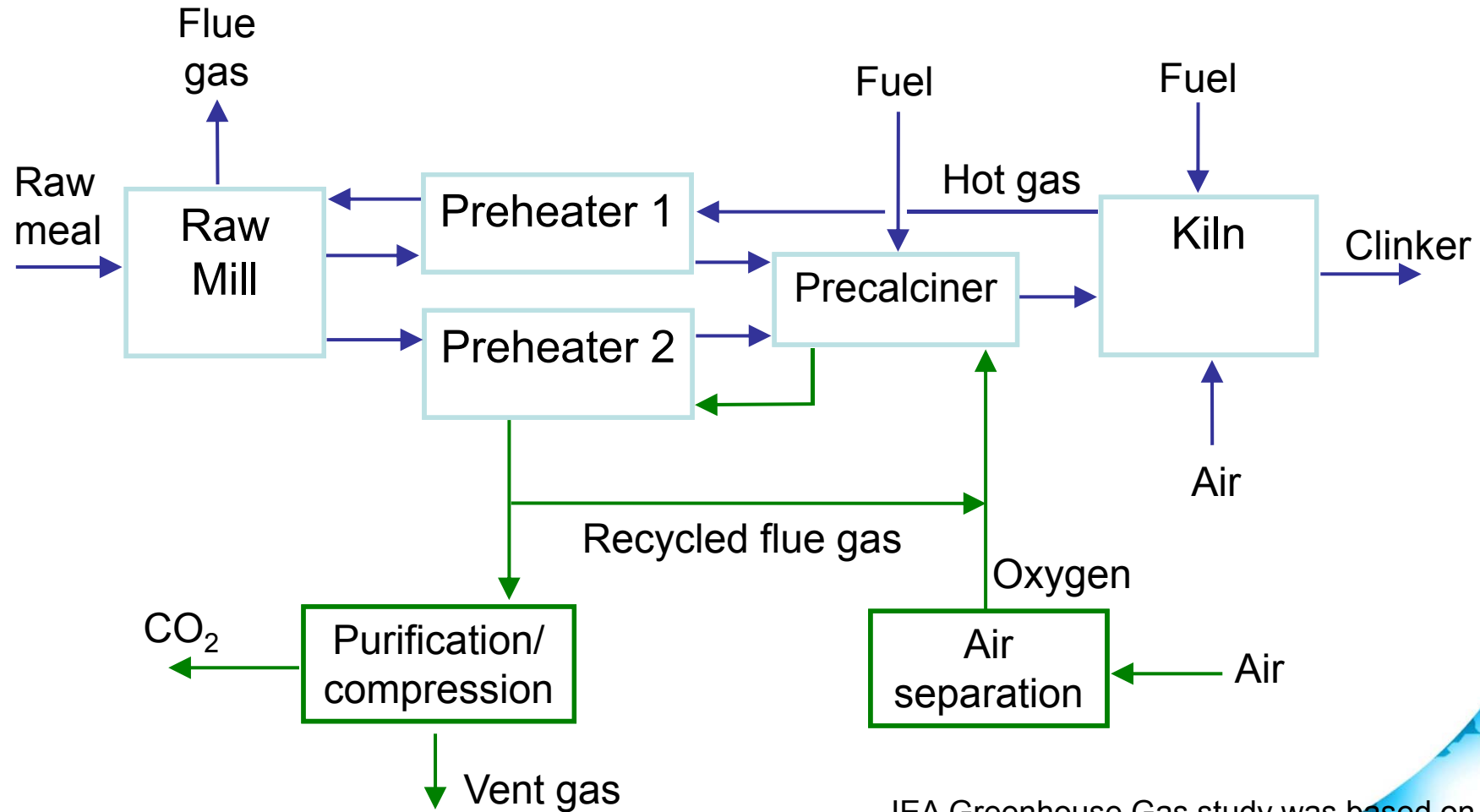
Figure 1. General arrangement of post-combustion CO₂ capture in a cement plant. The full animation can be seen at www.ecra-online.org.

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)

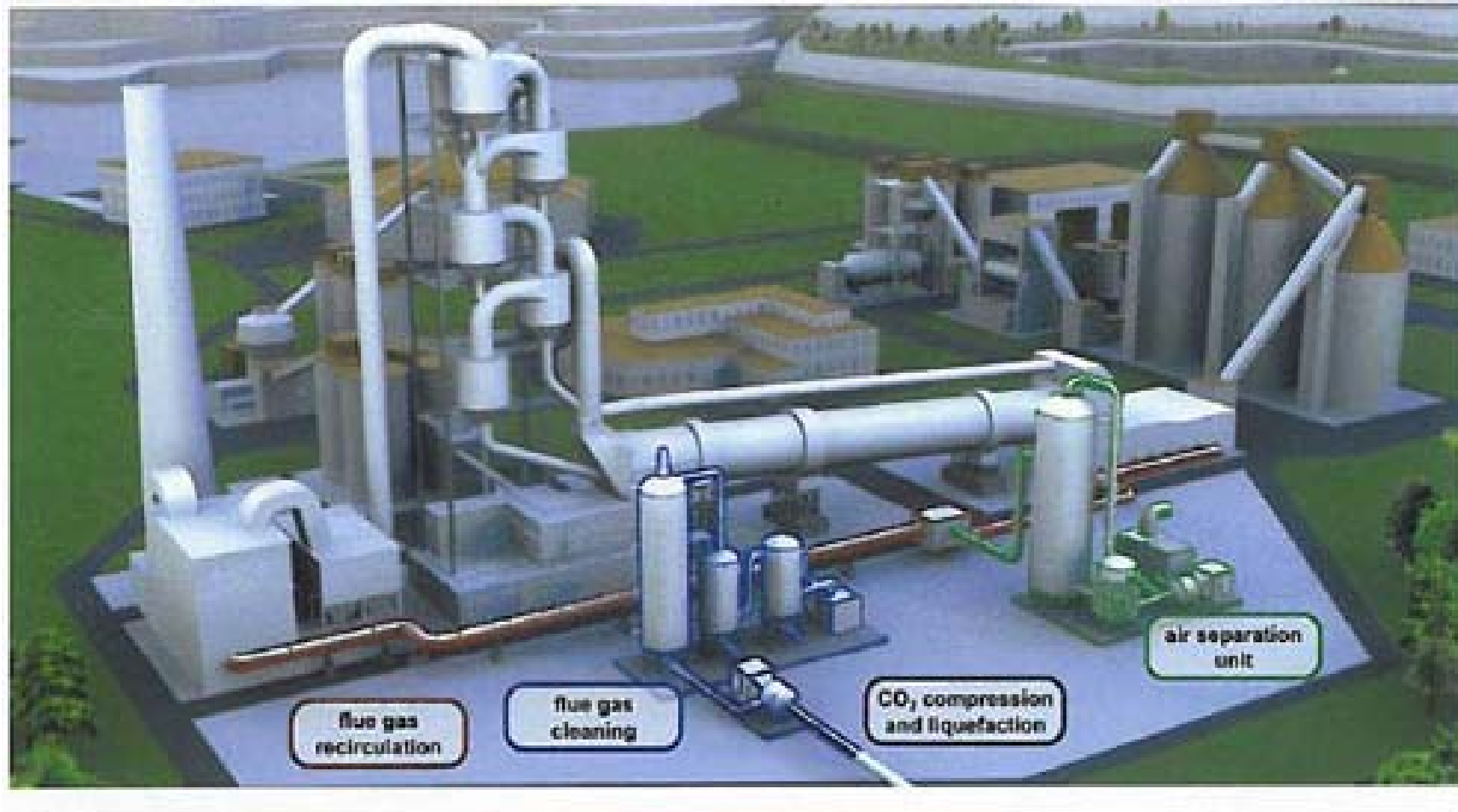


Figure 2. The general arrangement of oxyfuel technology on a rotary cement kiln.

Oxy-combustion Capture



- ***Advantages for cement plants***

- Low oxygen consumption
 - Compared to a coal fired boiler, 1/3 of the amount of 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



- *CO₂ 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 CO₂ 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 CO₂ 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

ECRA CCS Project: Research Consortium Phase III

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

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

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

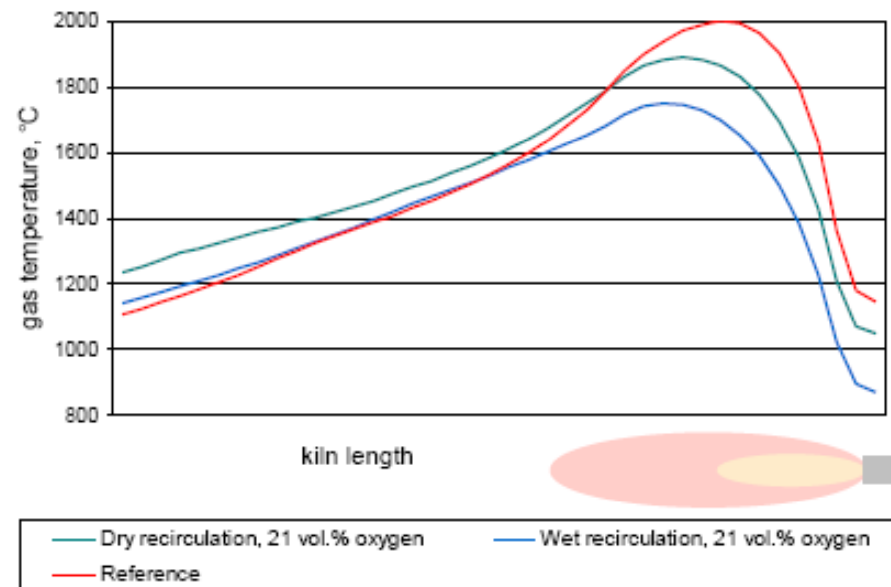
Oxy-fuel – Process modelling

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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