Global Experience with CCS Pilot Projects
CCS developments in cement: ECRA, Norcem

Rob van der Meer

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  - Post combustion
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- **NORCEM CCS project**

ECRA: The European Cement Research Academy

ECRA is an internationally recognized European research body in the field of cement and concrete technology.

ECRA was founded in 2003:

- as a platform to stimulate and undertake research activities in the context of the production of cement and its application in concrete
- to facilitate and accelerate innovation to guide the cement industry by creating and disseminating knowledge from research.
- ECRA initiates and provides seminars and workshops teaching state-of-the-art knowledge on cement and concrete technology and communicating the latest research findings
- ECRA undertakes dedicated research projects
- ECRA focuses on issues which individual companies may not be able to tackle
  alone and are of major importance to the cement industry as a whole

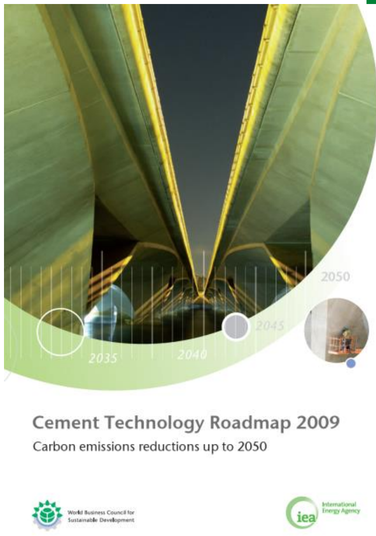
ECRA: Successful seminars and workshops

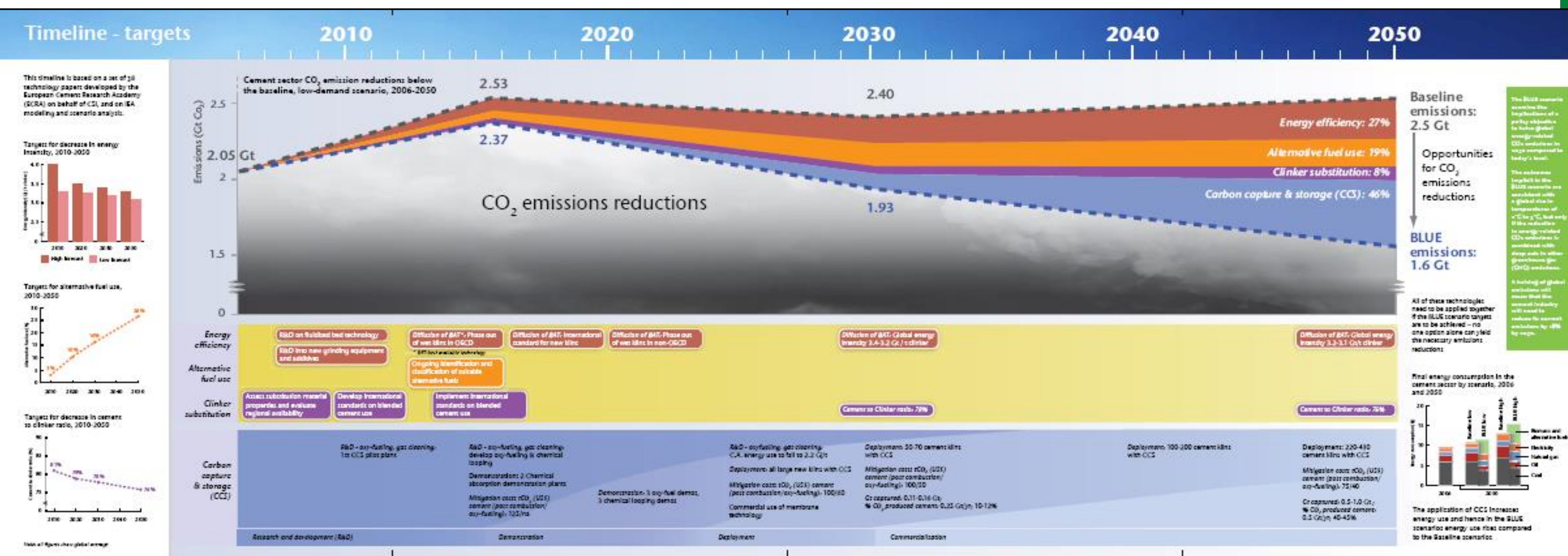
- **Examples of seminar/workshop topics**
  - Alternative fuels and raw materials
  - Grinding efficiency
  - Clinker reactivity and cement performance
  - CO_2 monitoring & reporting
  - Process technology
- **Seminars 2014**
  - Alternative Fuels: Quality and environmental control
  - Quality control of cement
  - CO_2 monitoring and reporting: Methods, experiences and new developments
  - Refractory materials and high temperature corrosion in the cement industry
  - Hydration of blended cements
- **Training Course 2014**
  - Clinker and cement production

WBCSD/IEA cement technology roadmap 2009

4 Levers for CO_2 emissions reductions

- Energy efficiency 27%
- Alternative fuels (biomass) 19%
- Clinker substitution 9%
- Carbon Capture and Storage 46%





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ECRA CCS project: Objectives

- Technical and economical feasibility of CCS technologies
- No focus on CO_2 transport and storage
- Integration of cement organisations: CSI, CEMBUREAU, PCA, etc.
- Joint research activities
- Cooperation with universities

ECRA CCS Project: Research Agenda

Phase I	Literature study (January - June 2007)	✓
Phase II	Study about technical and financial aspects of CCS projects, concentrating on oxyfuel and post-combustion technology (summer 2007 – summer 2009)	✓
Phase III	Laboratory-scale / small-scale research activities (autumn 2009 – autumn 2011)	✓
Phase IV	Prepare pilot plant (time-frame: 2 - 3 years)	
Phase V	Build and operate pilot plant (time-frame: 3-5 years)	
Phase VI	Demonstration plant (time-frame: 3-5 years)	

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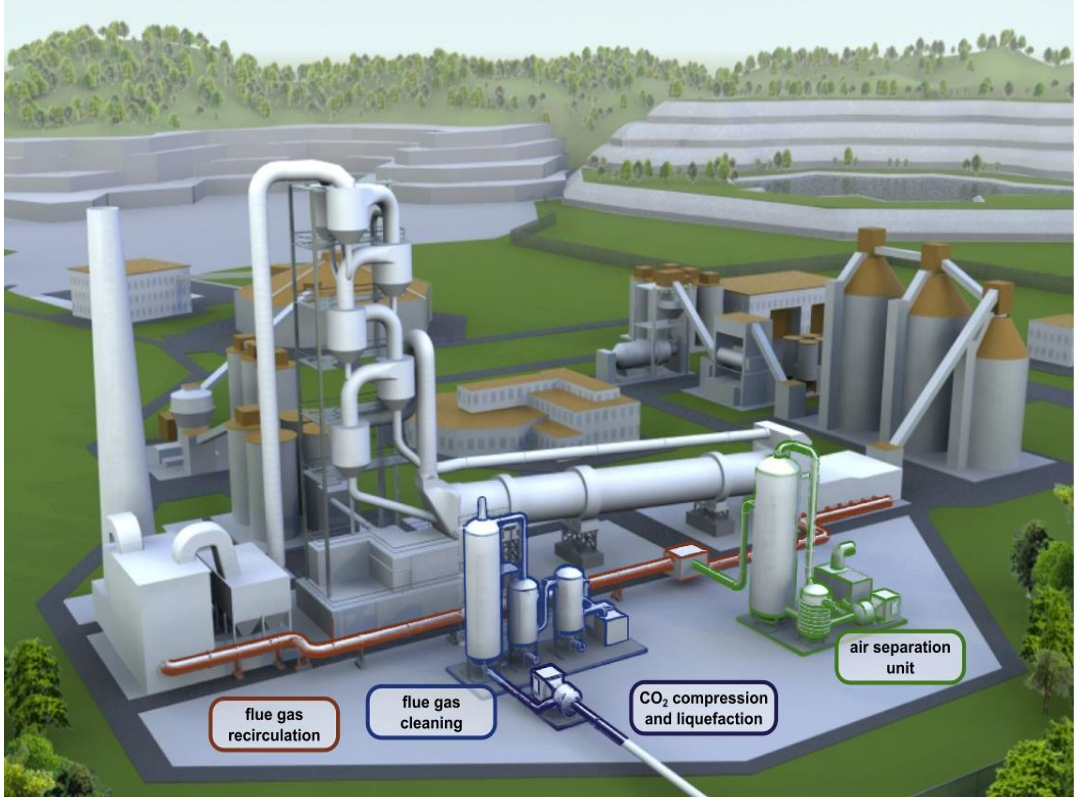
Oxy-fuel technology

- **Combustion with <u>pure oxygen</u> instead of ambient air**
- **Flue gas recirculation to regulate temperature level**
- **Integrated system**
- **<u>Doubling</u> of the electrical energy demand per tonne of produced cement**
- **Thermal energy demand constant**



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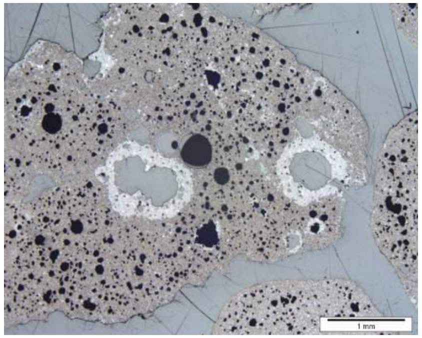
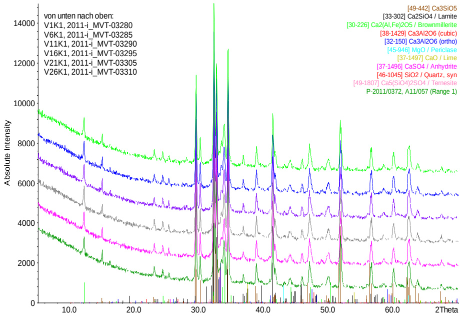
Limiting factors by quality and durability requirements

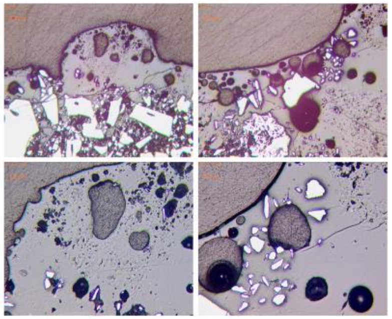




- **No serious influence on clinker composition**
- **Slight differences in cement properties (caused by Fe^{2+}) are in range of assured quality**

- **No negative influence on basic refractory material detected**
- **Using non-basic materials an increasing thermo-chemical reaction expected**
- **Adaption of refractory brickwork necessary**
- **Long-term test for evaluation advisable**

No barriers expected from clinker quality and refractory durability



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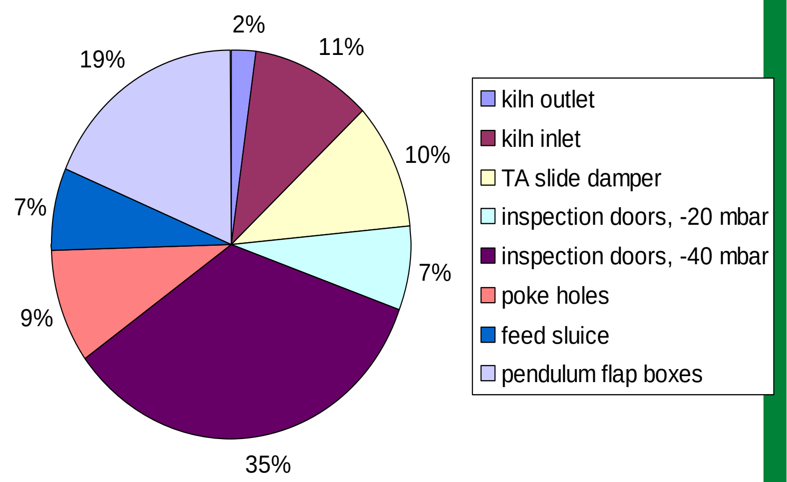
Flue gas conditioning decisive issues

- **Main influencing parameter: degree of false air intrusion**
- **Cost of CO_2 compression and purification ranges**
  - from about € 24 to about € 27/ton* depending on false air intrusion and CO_2 purity

*** at power costs of 0.071 €/kWh**

- **Capture rate of 90% possible.**
  At higher cost level capture rates of 99% are achievable.
- **Major intrusion from sealing locations like doors and poke holes**

- **Improved maintenance of these locations (gap reduction of 25%) would reduce intrusion to 6%.**
- **Singular sealing locations at kiln can be equipped with seal gas technology**

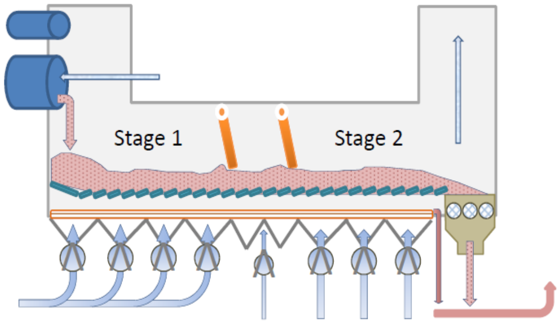


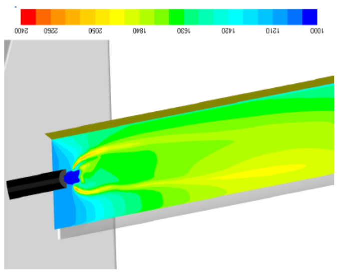
**Slight cost increase of CPU by impurities.
Decrease of false air by improved maintenance sufficient**

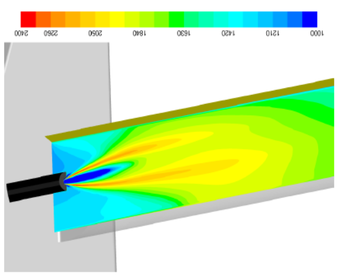
Not only CO2 captured !
SO2, Nox, heavy metals, etc

Retrofitting boundaries

- **Important aspect for the application of oxy-fuel in Europe**
- **Retrofitting an existing burner for oxy-fuel application is unlikely, but replacement by a suitable design is possible**
- **Designing a gas-tight two-stage cooler is feasible**
- **False air intrusion could be reduced to the greatest possible extent by overhauling/ replacing inspection doors and similar devices (< 6%)**
- **New safety and controlling devices necessary**
- **Space requirements of ASU/CPU**
- **Conventional behavior in trouble shooting restricted (no opening of doors/flaps in the plant etc.)**







Less limiting factors for retrofitting than expected

Phase IV - Deliverables

Phase IV. A:

- **Provide answers to the remaining challenges and further optimise the findings for a hypothetical medium sized plant (Work package A)**

- **Prepare the next steps towards a pilot kiln: work out detailed technical and economic concepts for a pilot-scale plant (Work package B)**

Phase IV. B:

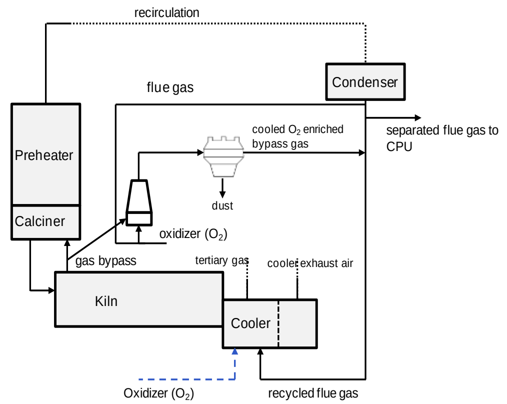
- **Work out detailed technical and economic concepts concerning the retrofitting of a full-scale existing plant (Work package C)**

Phase IV.A - Work packages

No.	Sub-package (short title)	Who?
A 1	Simulation study	Research Institute
A 3	Advanced cooler design	IKN
A 4	Future oxygen supply	Danish Technical University
A 5	Experimental verification of sealing potential	Irish Cement + Research Institute
B	Concept for a pilot plant:	
B 1	Plant capacity	Aixergee
B 2	Design principle	Aixergee
B 3	Dimensioning	CINAR + Fives FCB (supported by Research Institute)
B 4	Control and safety devices	n.n. (retendering)
B 5	Cost estimation	n.n. (retendering)
B 6	Concept for reuse	Subgroup
D1	CO_2 overall balance	Student work
E	Coordination	Research Institute

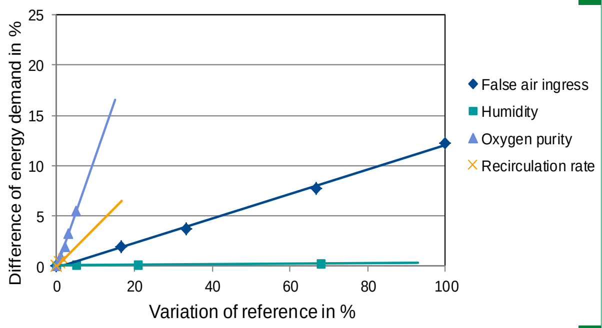
Work package A1

- **Simulation study:**
- **Task assigned to: Research Institute**
- **Objectives:**
  - Integration of all findings from phase III
  - Simulation of different capacities and plant layouts, process fluctuation and application of alternative fuels/ bypass
  - Concept for switching mode



Progress:

- Evaluation of impact of plant capacity/ alt. fuels, false air ingress, ASU and condenser performance and recirculation rate on energy demand
- Concept for bypass system and switching mode



Status: Programming work and further simulations progressing

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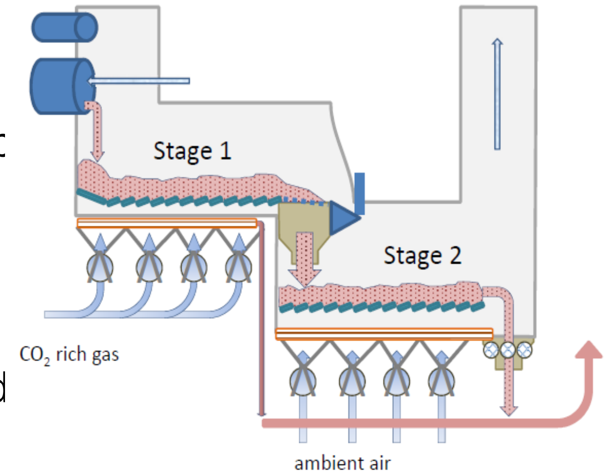
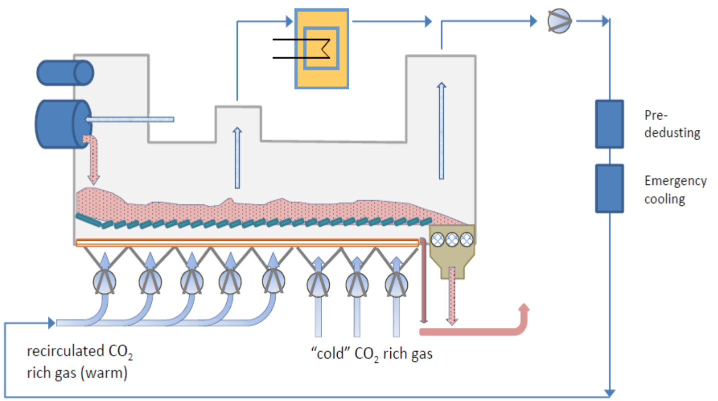
Work package A3

- **Advanced cooler design:**
- **Task assigned to: IKN**
- **Objectives:**
  - Further development of advanced cooler concep
  - Minimizing the risks of the concepts of phase III
  - Evaluation of acceptable gas-tightness

Progress:
  - Two potential concepts developed and balanced (Intermediate Chute, Gas Recirculating Cooler)
  - Evaluation of pro/cons, recommendations

Status: Final report in progress





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Work package A5

- **Experimental verification of sealing potential:**
- **Task assigned to: Irish Cement, Research Institute**
- **Objectives:**
  - Experimental evaluation of best practice maintenance for false air reduction
  - Measurements (2 trials), long term inspection

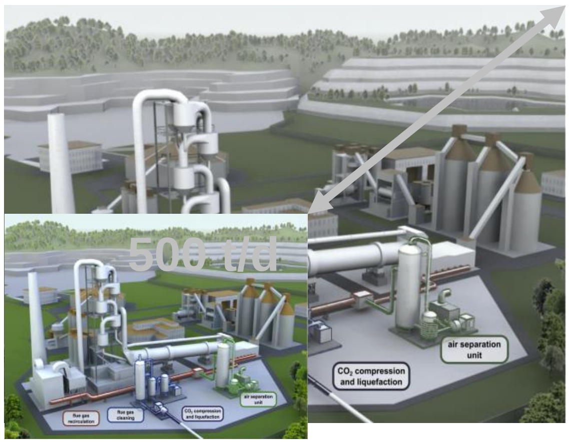
Progress:

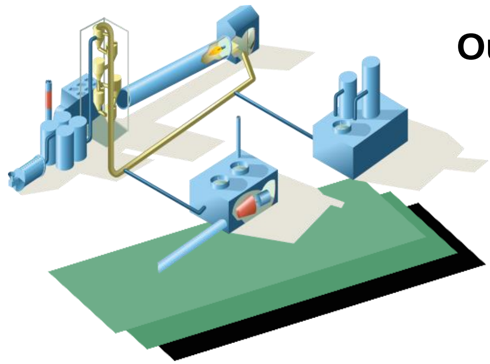
  - Trials conducted and evaluated
  - Identification of reference (15 %) and improved maintenance (8 %) false air intrusion level

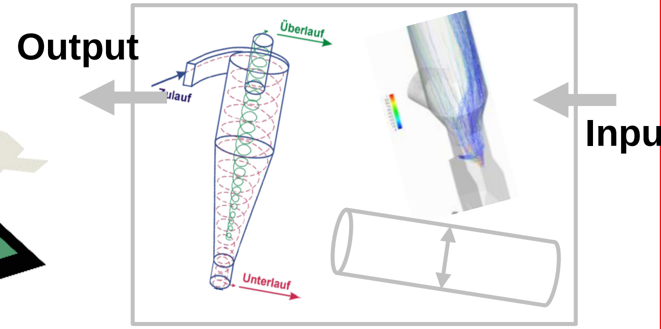
Status: Student’s report available,
long term inspection on-going

Work package B: Concept of a pilot plant

- **B1: Suitable plant size** **B2: Design** **B3:Dimension**

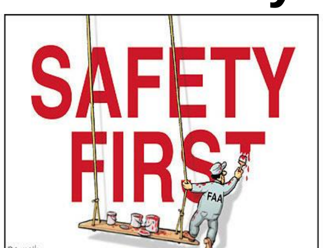




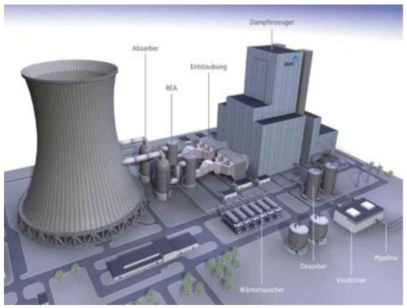


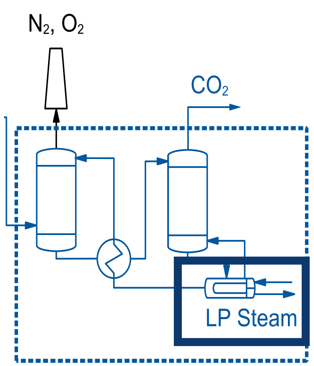
Concept

- **B4: Control of and safety concept** **B5: Costs estimation** **B6: Concept for reuse of the plant**



CCR: Utilization of captured CO_2 for MeOH or CH_4





CO_2 sources like power plants, cement plants, etc.

CO_2 capture technologies

CO_2

H_2 production with regenerative energies

H_2

Methanol or methane production

Carbon capture project in Brevik

- The first capture project in the cement sector
- We are in need of more accurate knowledge
- Cement plants suitable for CO_2 capture
  - High concentration of CO_2
  - The flue gas is more “polluted”
  - Available heat energy from kilns
- Energy efficiency
- Costs (CAPEX and OPEX)

Project information

International project on behalf of the cement sector in Europe

Partners:

Norcem, HeidelbergCement og ECRA
(European Cement Research Academy)

Funding:

- State funding through Gassnova (Climit program): 75 %
- Total budged: 93 MNOK (11,7 M€)

Project period:

3, 5 years from May 2013

Four capture technologies for testing

Technology	Supplier	
Amine technology	Aker Clean Carbon	
Membrane technology	DNV KEMA, NTNU & Yodfat Engineers	
Solid sorbent technology	RTI	
Calcium Cycle (Carbonate Looping, RCC)	Alstom Power	

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Cooperation with technology providers: ACC

- **Amine scrubbing technology**
- **Mobil Test Unit (MTU)**
  - 40 foot container
  - Absorption tower: 25 m
  - Stripper: 13.4 m
- **Capacity: 2,000 t CO_2/ year**