



Norcem CO₂ Capture Project

CSLF PIRT – Meeting 27. October 2014

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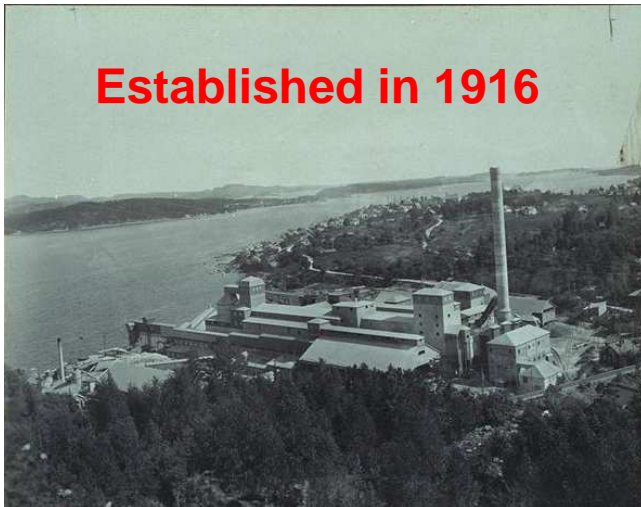
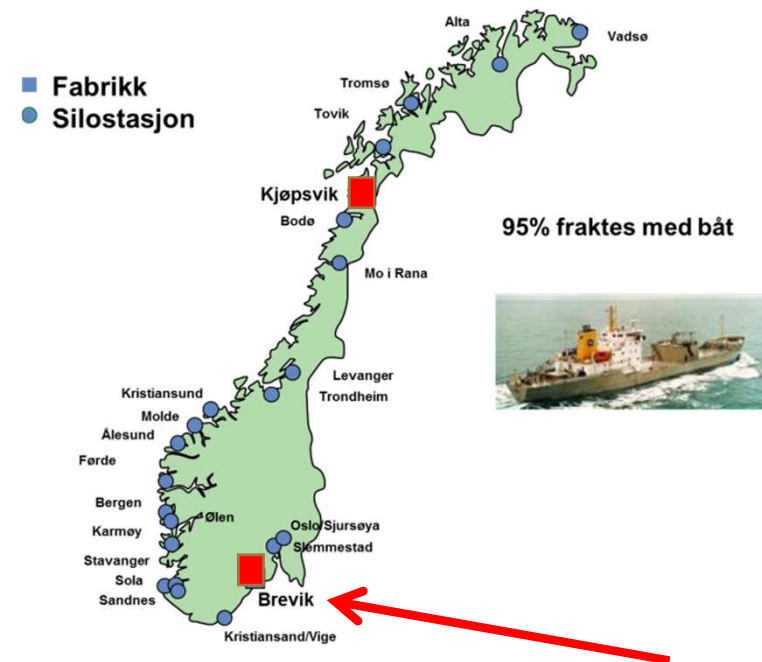
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■ Outline

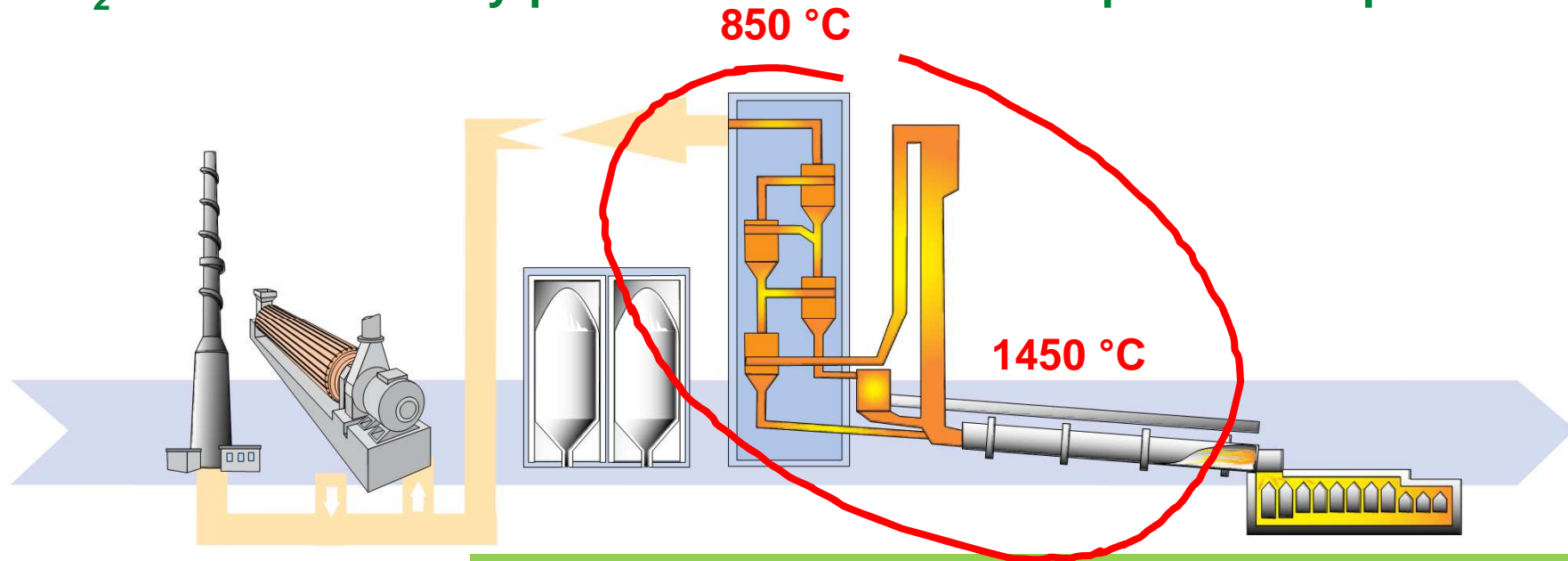
- Norcem at a glance
- Background – CO₂ emissions in the cement industry
- Project mandate and scope
- The 4 Capture Technologies and Current Status
- Benchmark Study & Full Scale Perspective
- Conclusions

Norcem AS

- Norcem only cement producer in Norway with its 2 plants:
 - Norcem Brevik
 - Norcem Kjøpsvik
- Part of HeidelbergCement since 1999
- Middle sized cement plant → 1.3 mill tons/ year
- One of the most modern cement plants in Europe
 - Utilisation of alternative fuels: 60 % → 75 %
 - Equipped with SO_x- and NO_x-scrubbers



CO₂ – Unavoidable by-product from the cement production process

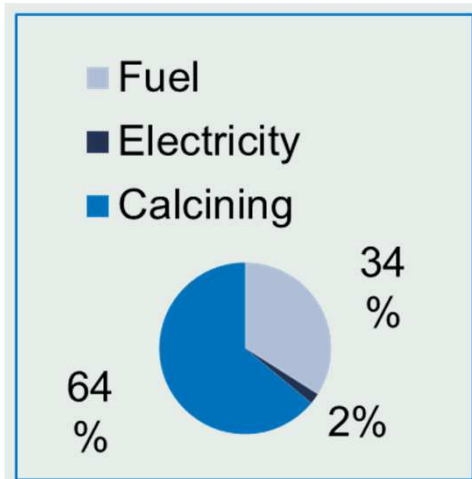


Two main CO₂ sources:

- 1) 2/3: Raw Materials ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2\uparrow$)
- 2) 1/3: Fuels (Cyclone Tower & Kiln System)

Globally: 5 % (1,9 Gt CO₂ annually)
Europe: 20 % (2011)
Norway: 2.6 %

HeidelbergCement: ~ 50 million tonnes annually
Norcem Brevik: ~ 800 000 t CO₂ annually



■ Norcem CO₂ Capture Project

- **Project launched in May 2013 - plan to conclude in Mar 2017**
- **Project on behalf of the European Cement Industry!**
- **Partners:**
 - **Norcem**
 - **HeidelbergCement**
 - **ECRA (European Cement Research Academy)**
 - Role: Technical support & dissemination of project results
- **Total budget: 93 M NOK (11.7 M €)**
- **Gassnova / Climit-Program: 75 % funding**

Mandate and main objectives

- **Study and compare various CO₂ capture technologies.**
 - Various development level
- **Qualification of technologies:**
 - Determine how suitable these are for implementation in modern cement kiln systems.
- **Transport and storage is not part of the study**
- **Important focus areas:**
 - CO₂ Capture rate, energy consumption, performance impact due to flue gas impurities, costs (CAPEX/ OPEX), space requirement
- **Full Scale Perspective**
 - Utilization of waste heat
 - Full scale not necessarily 100 % capture

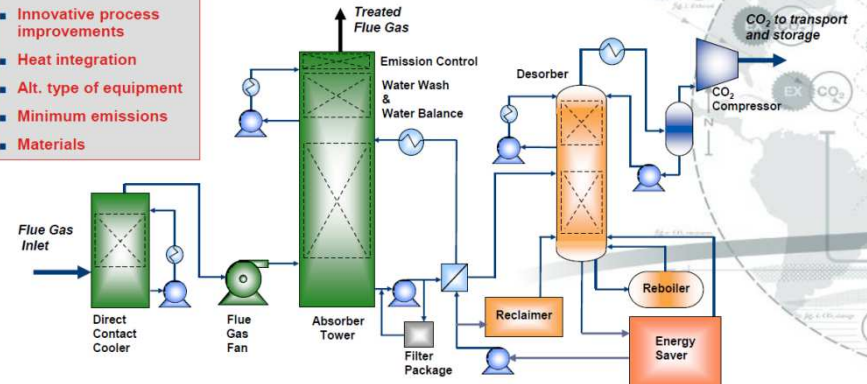
Aker Solution | Amine Technology



Advanced Carbon Capture Process

New design elements:

- Low energy amines
- Innovative process improvements
- Heat integration
- Alt. type of equipment
- Minimum emissions
- Materials



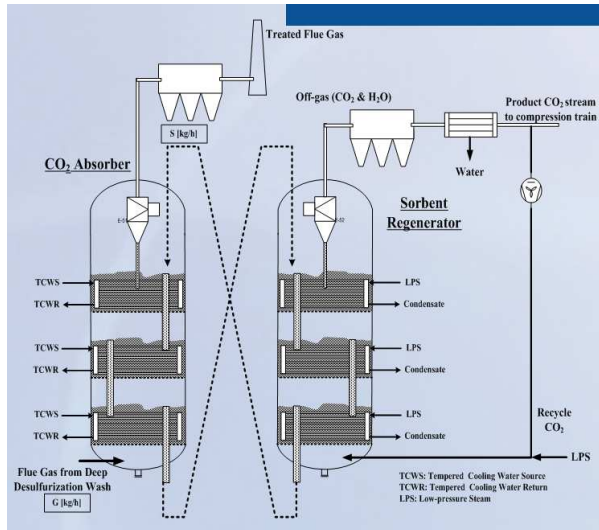
- **Mobile Test Unit – Capacity 0,2 t CO₂/h**
- **6 months test program (May – Oct 2014)**

- **Solvent: Amine mixture – S26**
- **2000 operating hours/ 200 t CO₂ Captured**

- **Promising preliminary results**
 - More than 90 % Capture rate, energy consumption (RBD) in the range of other applications, low amine consumption and degradation, low emissions (degradation products detected)

- **Final report: End of 2014**

RTI - Research Triangle Institute | Solid sorbent technology



- 3rd generation technology
 - 3 month performance testing (Apr – Jun 2014) – Completed
 - Thermal swing packed bed reactor system – Bench Scale
 - Solid Sorbent: Poly-imide-based
 - Capacity: 3-5 SLPM (Real flue gas)
-
- Promising preliminary results
 - 300 absorption/ regeneration cycles
 - 100 % capture
 - Performance indicator - Sorbent loading: 5-7 wt%

RTI – Phase II

Phase II:

- Long term performance testing
- 3-floor pilot
- Flue gas: 500 – 1500 SLPM
- New absorbents with higher loading capacity (9-11 wt %)

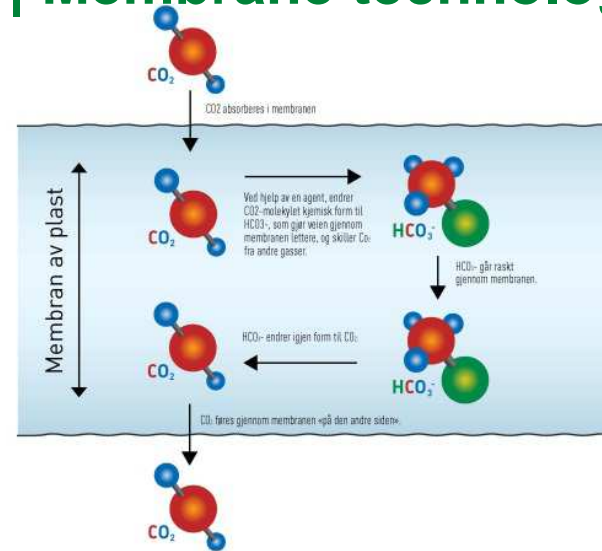
- Schedule: Sep 2014 – Jun 2016

- Full scale perspective



Phase II pilot

DNV GL, NTNU & Yodfat Engineers | Membrane technology



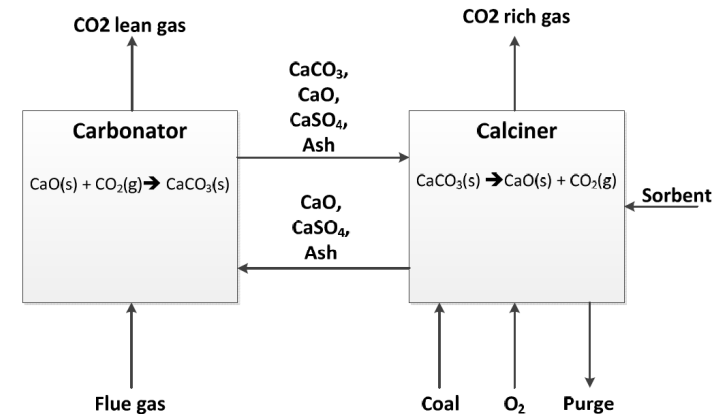
- 3rd generation technology
- Fixed Site Carrier (FSC) Polymer Membrane (NTNU)
 - Poly-sulphonate membrane with a poly-vinyl-amine layer
- Test program (Mai - Oct 2014):
 - 1-stage module – Flat sheet membrane – Area: 1.2 m²
 - Cassette system
 - No circulation of FG
 - FG: 10-50 Nm³/h
- Preliminary results:
 - Promising durability (high tolerance of FG)
 - Membrane performance; 60-70 % CO₂ recovery
- Final report Nov 2014
 - Modelling full scale perspective



Alstom Power | Calcium-Looping



Pilot at IFK Stuttgart

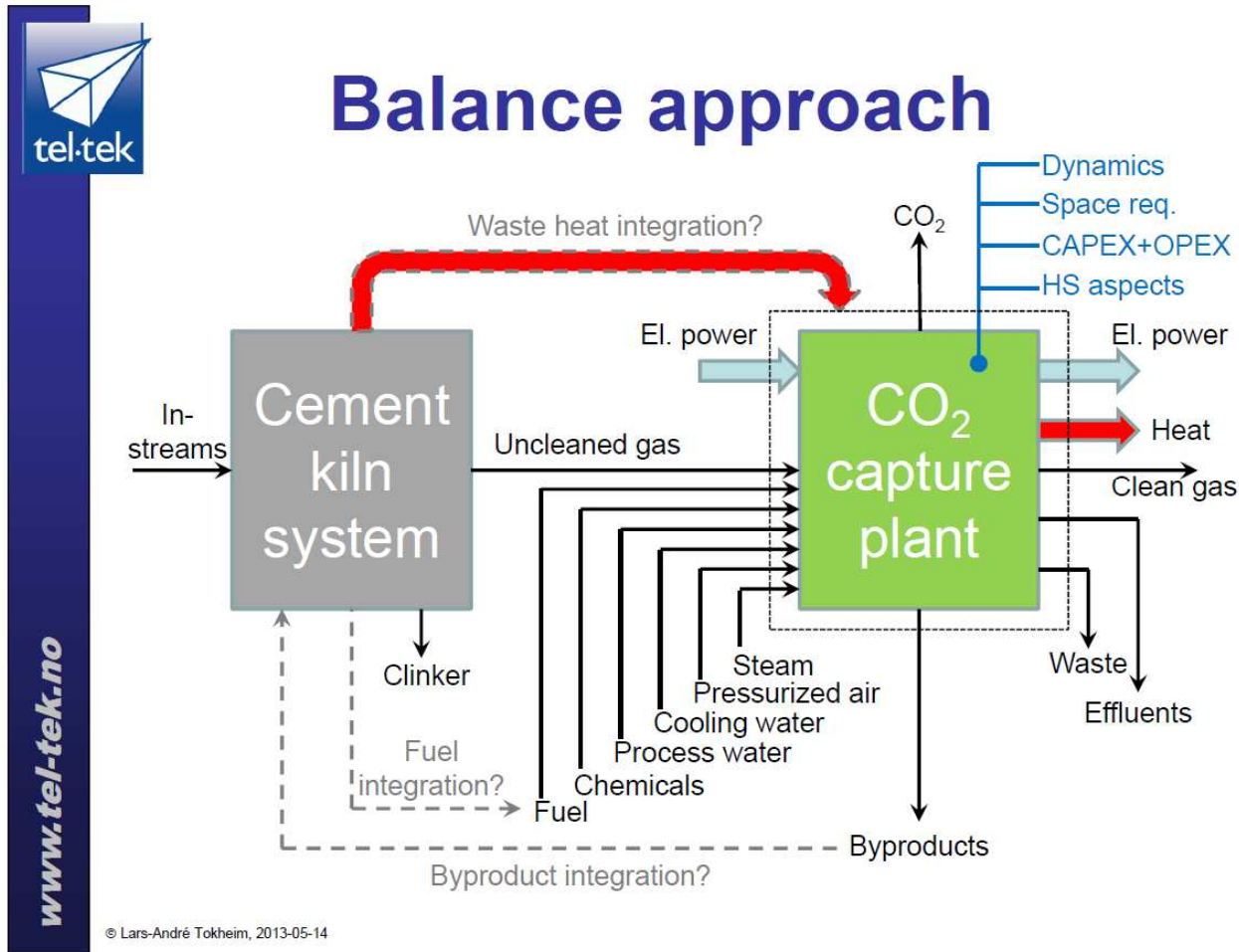


- 2nd generation technology
- Dual-Fluidized bed system → 200 kWth test pilot (Stuttgart University)
- Combustor system -- > Real flue gas
- Calcium Looping – using limestone to absorb the CO2
 - $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ (Regenerator – Calciner 900°C)
 - $\text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3$ (Absorber – Carbonator 650°C)

Pilot testing

- Two test campaigns – 1 week each/ 24-7 operation
 - More than 90% CO2 capture
 - Sorbent reactivity
 - Circulation pattern between reactors – close material balance
 - Sorbent degradation over time
 - Limestone from Norway (Verdal)
- 1 year program – objective → remove risks for further development of technology
- Construction of a much larger demonstration unit is the logical next step
- Final report end of 2014

Benchmark Study | Commercial Scale Perspective



■ Benchmarking - Three cases

■ Case 1 (reference):

- Full-size (minimum 85 %) cleaning, no waste heat available

■ Case 2:

- Full-size (minimum 85 %) cleaning, waste heat available as per Norcem Brevik

■ Case 3:

- Reduced-size cleaning, based on a cost-optimal utilization of waste heat at the Brevik plant. In this case, the TP will decide which capture ratio is cost-optimal.

Conclusions

- **CO2 emission is an unavoidable by product from the calcination reaction**
- **Carbon capture seems to be the only technology to significantly reduce the GHG-emissions**
- **We need to obtain knowledge and experience from real testing**
- **4 post-combustion technologies are demonstrated**
- **Major part of planned testing will be executed in 2014**
 - RTI continue into a phase II
- **Benchmark Study – Important outcome of the project – Comparison of technologies in a commercial scale perspective.**
- **Commercial scale not necessarily 100 % capture**
- **Before summer 2015 Norcem will have much more knowledge regarding the realism of industrial carbon capture; especially in the cement industry**
 - Benchmark Study will be updated after RTI Phase II
- **Need a market for CO2 (transport & storage/ reuse) for realization on technology concept**

Acknowledgement

- **Norcem would like to acknowledge Gassnova (Climit program) for providing required project funding, which has been vital for execution of the project.**
- **Norcem will as acknowledge ECRA for their invaluable support both technically and their important role in dissemination of project information and results.**
- **Moreover, Norcem will acknowledge the technology providers; Aker Solutions, Research Triangle Institute (RTI), Alstom Power and the consortium of DNV GL, NTNU and Yodfat Engineers for their interests and engagement demonstrating their technology at Norcem Brevik.**
- **Thanks to HeidelbergCement Northern Europe Management team and the Norcem Brevik organization which are and have been extremely positive and supportive in carrying out this important project.**



Thank you for your attention!