Results and Outcome from Norcem CO2 Capture Project
CSLF – 23. Apr 2018

Liv Bjerge, Sustainability Manager HC Norway
HeidelbergCement – a global actor within building materials

- Second largest company in the world within cement, concrete and aggregates
- 60,000 employees
- Located in more than 60 countries
- Aggregate reserves: 20 billion tonnes
- Cement capacity: 194 million tonnes
- CO2 emissions: ~ 70 million tonnes/year
- Part of region Northern Europe – 5,000 employees
- In Norway: Norcem Brevik & Norcem Kjøpsvik
- Brevik Plant:
  - 1,3 million tonnes cement
  - 1 million tonnes CO2/ y
We need carbon capture to fulfill our Zero Vision

Liv Bjerge - Sustainability Manager HeidelbergCement Norway

- CO2 emission is an unavoidable by product from the calcination reaction
- Carbon capture seems to be the only technology for CO2 mitigation in the cement industry
- We need to obtain knowledge and experience from real testing
- 4 post-combustion technologies are selected
- Major part of planned testing will be executed in 2014
- 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
- Need a market for CO2 (transport & storage/ reuse) for realization on technology concept
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
**Selected technologies in Phase I and II**

### Phase I:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Amine Technology (S26)</td>
<td>Aker Solutions, TRL 8-9</td>
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<tr>
<td>Membrane technology (FSC – Flat sheet)</td>
<td>MC: NTNU, DNV GL, Yodfat Engineers, TRL 4-5</td>
</tr>
<tr>
<td>Solid Sorbent absorption technology RTI (Phase I)</td>
<td>RTI (Phase I), TRL 5</td>
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<tr>
<td>Regenerative calcium cycle, Alstom Power</td>
<td>TRL 3</td>
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### Phase II:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Details</th>
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<tbody>
<tr>
<td>Solid sorbent absorption technology RTI (Phase II)</td>
<td>NTNU &amp; Air Products, TRL 5!</td>
</tr>
<tr>
<td>Membrane technology MemCCC – <strong>New project with own financial support</strong></td>
<td>NTNU &amp; Air Products, TRL 5!</td>
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Main results from testing

- Project itself has been a great success even not all results are as expected or wanted.

- Both Norcem and technology providers have learned a lot from pilot design and construction, preparations of infrastructure & utilities and testing on real conditions.

- MC/ MemCCC → exposure testing → focus on sorbent/ membrane performance/ lifetime and make the technology work as expected and performed under ideal conditions in lab. Pilot quality & operational problems.

- RTI experienced difficulties in design when upscaling from bench scale to 3-floor scale pilot.

- MC/ MemCCC, RTI and Alstom: A lot of assumptions had to be assumed and included by us to be able to evaluate the full scale economic performance (Benchmark Study).

- Aker Solutions → only vendor that managed to deliver full scale design incl. economic calculations.

- RTI and MC/ MemCCC did not manage to mature the technology from Phase I to Phase II.

- Total Annual Cost, TAC: In the range from 40 to 59 EUR per ton of CO2 avoided at plant level.

- All costs have increased from Phase I to II!

- Aker Solutions amine technology is by far the most mature technology – TRL 8-9 and ready for full scale demonstration.
Lessons Learned

- For Norcem and the technology providers it has been of vital importance to test under real conditions

- Norcem has learned a lot being host for the test programs → much more resource-demanding than first anticipated

- Very different demand for support!

- The exhaust gas experiences much more «aggressive» than first expected

- Transport of representative flue gas was not straightforward (avoid heat loss and condensations is a must!)

- Important to construct quality pilots – even though the test campaign is short!

- Presence is a «must» when you are developing new technology!

- Commercial partners is a «must» in order to ensure necessary drive towards commercialization!

- We have developed a quite good Benchmark analysis tool which gave us the opportunity to compare apples with apples!

- Time consuming to develop capture technologies and upscaling is more time consuming that anticipated!

- Close dialog with Gassnova – priceless!
Back up slides
The Norwegian full scale CCS Demonstration Project

**CO₂-CAPTURE**
- Norcem HeidelbergCement
  - Cement production
- Yara Porsgrunn
  - Ammonia production
- Fortum Oslo Varme AS
  - Waste-to-energy plant

**CO₂-STORAGE**
- Planning by Statoil and partners
- Intermediate storage on shore
- Offshore storage in the North Sea
- Huge capacity

**CO₂-TRANSPORT**
- By ship
- Responsibility Statoil

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Full Scale Carbon Capture at Norcem Brevik

<table>
<thead>
<tr>
<th>Concept Study Results 2017</th>
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<tbody>
<tr>
<td>Technology</td>
<td>Aminsolvent</td>
</tr>
<tr>
<td>Technology provider</td>
<td>Aker Solutions</td>
</tr>
<tr>
<td>Capture capacity</td>
<td>400 000 t/ år</td>
</tr>
<tr>
<td>Excess heat</td>
<td>46 MW</td>
</tr>
<tr>
<td>Intermediate storage CO2</td>
<td>5 300 t</td>
</tr>
<tr>
<td>Cost estimates (CAPEX/ OPEX)</td>
<td>± 30 %</td>
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Concept study – Layout/Integration with existing cement plant

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The road to a possible project realization:

- May - June 2018: Political process in Parliament

- If positive Parliament decision:
  FEED project
  Appr. 12 months execution - finalized Q2/2019
  New QA-process and Parliament decision (and in parallel internally in HC) regarding realization at the earliest Q4/2019

- Construction period at Norcem Brevik: Approx. 3 – 3,5 years
- Ready for startup: 2023?
We cross our fingers for a positive decision in the Parliament!

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