CARBON CAPTURE IN CEMENT INDUSTRY

Rob van der Meer
1. CEMBUREAU

2. EU set of policies

3. CEMBUREAU’s roadmap to carbon neutrality

4. Carbon capture

5. Outlook

6. Conclusions
World Cement Production 2019: 4.1 bn Tonnes

- World volume oscillating since few years around 4 mio T
- Top 3: China, India, rest of Asia
Today: 29 Members
(26 full Members and 3 Associate Members)

Full Members = national cement industry associations and cement companies of the European Union (with the exception of Malta) plus Norway, Switzerland, and the UK

Croatia, Serbia and Slovakia are Associate Members of CEMBUREAU

Cooperation agreement with Vassiliko Cement (Cyprus) and with the Cement Association of Ukraine
CEMENT & CONCRETE KEY ENABLERS FOR THE LOW CARBON ECONOMY

Quarries → Clinker → Cement → Concrete
limestone → grinding

Cement (10%-15%) → Water (15%-20%) → Aggregates (65%-75%)

SUSTAINABLE TRANSPORT

RENEWABLE ENERGY

THERMAL MASS
✓ If we do not act, change will come from outside

Customers/Construction companies
NGO’s

✓ Climate targets increasingly enshrined in binding law
  - German Government increased emission reduction target from 55% to 65% by 2030 and aims for climate neutrality by 2045 instead of 2050 after Constitutional Court ruled former targets unconstitutional
  - Dutch Court orders Shell to cut emissions by 45% by 2030

✓ Overhaul of climate change policies worldwide

✓ Investors/banks are “greening” their investments (taxonomy)

✓ 260 plants spread across the while CEMBUREAU area
  - How to ensure we take plants further away from industrial hubs on the journey?
The Green Deal

GREEN DEAL REQUIRES FROM INDUSTRY

... significant investments

... workforce transformation
... there is more than climate

ENERGY
- Impact on cost basis
- Strong renewables development

<table>
<thead>
<tr>
<th>Year</th>
<th>Solar</th>
<th>Wind</th>
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<tbody>
<tr>
<td>2022</td>
<td>206 GW</td>
<td>203 GW</td>
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<tr>
<td>2030</td>
<td>592 GW</td>
<td>510 GW</td>
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<tr>
<td>Annual increase</td>
<td>48 GW</td>
<td>36 GW</td>
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SOCIAL
- Disconnect between EU and citizens/workers
- National election result tend to favour extremes / centre becomes smaller

COMPETITIVENESS
- No strong industrial policy?
- Net zero Industry Act
- EU response to US IRA
- Sanctions and cutting off energy from Russia took the upper hand over building sufficient energy capacity in Europe
CEMBUREAU’S RESPONSE
THE 5C APPROACH

CLINKER
CEMENT
CONCRETE
CONSTRUCTION
CARBONATION
CEMBUREAU 2050 roadmap

-51
5C - Construction Carbonation

-116
2017 emissions

-160
5C - Clinker

Decarbonated raw materials - 27
Biomass Fuels - 71
Thermal efficiency - 26
Low carbon clinker - 17
H₂ & Electrification - 19

1990 emissions
783 kg CO₂/t of cement

2050 emissions
0 kg CO₂/t of cement down the value chain
CEMBUREAU 2030 roadmap

CO$_2$ reduction along the cement value chain (5Cs: clinker, cement, concrete, construction, re-carbonation)
Main Policy Requests

**Carbon Capture, Use and Storage (CCUS)** will account for 42% of the CO$_2$ emissions reduction in the sector. The EU should urgently look at developing a pan-European CO$_2$ transportation and storage network, provide continued funding to demonstrators and support the business case of the technology through State Aid.

The replacement of fossil fuels by non-recyclable and biomass waste, and the use of alternative raw materials, will deliver another 15% of the emissions reduction in the cement industry. Policies should support this circular approach by facilitating waste shipment between EU countries, and discouraging both landfill and exports of waste outside of the EU.

Bringing low carbon-cements products to the market will deliver an additional 13% emissions reduction. Upcoming policies should aim to reduce European building’s CO$_2$ footprint, be based on a life-cycle approach, and incentivise the market uptake of low-carbon products.

A level playing field on carbon, regulatory certainty as well as an ambitious industrial transformation agenda, will be pivotal to deliver the investments needed to achieve carbon neutrality.
Opportunities to Achieve CO$_2$ Reductions for Clinker

-27 Decarbonated raw materials

-71 Biomass

2017 emissions 667 kg CO$_2$/t cement

2050 emissions 227 kg CO$_2$/t cement

-26 Thermal Efficiency

-17 New Cements

-19 H$_2$ Fuel & Electrification

-280 CCS/U

Access to alternative decarbonated raw materials
Zero landfill, improved waste sorting, better implementation of waste legislation.

Access to biomass waste, Zero landfill, improved waste sorting, better implementation of waste legislation.

Investment in kiln upgrades and waste heat recovery.

Access to funding for research, take-up of low carbon products efficient revision of standards.

Access to H$_2$ and sufficient renewable electricity.

Access to public funding for innovation, CO$_2$ pipeline infrastructure, Access to Renewable Electricity, High CO$_2$ price, Ability to pass on CO$_2$ costs.
How can we reduce emissions from clinker?

**Alternative Decarbonated Raw Materials**
CEMBUREAU envisages up to a **3.5% reduction of process CO\(_2\)** using decarbonated materials by 2030 and up to **8% reduction by 2050**.

**New types of Cement Clinkers and the use of Mineralisers**
CEMBUREAU has targeted a **2% reduction in process CO\(_2\) emissions by 2030** and **5% by 2050**. These numbers consider limits in application of some of these cements and the time needed for market acceptance.

**Thermal Efficiency**
CEMBUREAU is targeting a **4% improvement** in thermal efficiency by 2030, moving to **14% in 2050**.

**Carbon Capture, Utilisation and Storage (CCUS)**
By 2050 the total use of the different carbon capture techniques will reduce CO\(_2\) emissions by **42%**.

**Fuel Substitution and Zero Fuel Emissions Research**
CEMBUREAU targets to reach **60% alternative fuels containing 30% biomass in 2030**, and **90% alternative fuels with 50% biomass by 2050**.
Abbreviation CCUS

1. CCS Carbon Capture and Storage
2. CCU Carbon Capture and Use
   Carbon Capture and reUse
3. CCV Carbon Capture and Valorization

- CCS Carbon Capture and Something

**Fundamental**

Three elements within these abbreviations

1. Carbon Capture
2. Storage
3. Use / reUse / Valorization
• Carbon Capture is about how to capture that CO₂
• Three types of technologies
  1. Pre Combustion Capture doesn’t make sense in cement
  2. Post Combustion Capture
  3. Oxyfuel Combustion and others
Typical Post Combustion Capture processes
- Amine absorption: Technology from 1930, well known in chemicals concept to be used in Brevik, Norway
- Chilled ammonia: More complicated and challenging
- Membrane separation: New technologies...... R&D phase

Oxyfuel and other processes
- Oxyfuel process: New type of cement production process
- Direct separation: E.g. Leilac
- Calcium looping: Too complicated to explain

Post Combustion Capture = End of Pipe Technology

Pure CO₂ gas/liquid/solid
Amine absorber basic design

Test unit in Brevik (2015 – 2018), Norway

Lay out for demo-scare project in Brevik
Oxyfuel process

Exhaust gases, high in CO2

Oxygen

Recirculation of CO₂

- Research done by ECRA, CemCap (with Sintef)
- Pilot projects / Demo projects planned
  - Westküste 100 = Holcim
  - Catch4Climate = Schwenk, Vicat, Dyckerhoff, HeidelbergCement
Direct separation

- LeiLac projects in Lixhe (Be) & Hannover
- Split between combustion emissions and process emissions
  - Clean stream of process emissions

\[ \text{Carbonate} \quad \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \quad 60\% \text{ “process” emissions} \]
Geological Storage Options for CO₂

1. Depleted oil and gas reservoirs
2. Use of CO₂ in enhanced oil recovery
3. Deep unused saline water-saturated reservoir rocks
4. Deep unmineable coal seams
5. Use of CO₂ in enhanced coal bed methane recovery
6. Other suggested options (basalts, oil shales, cavities)
Overview IEA (2021)

- **Fuels**
  - methane
  - methanol
  - gasoline/diesel/aviation fuel

- **Chemicals**
  - chemical intermediates (methane, methanol)
  - polymers (plastic)

- **Building materials**
  - aggregates (filling material)
  - cement
  - concrete

**Conversion**

- Fossil fuel
- Biomass
- Underground deposits

**Non-conversion**

- Industrial process

**Yield boosting**
- greenhouses
- algae
- urea/fertiliser

**Solvent**
- enhanced oil recovery
- decaffeination
- dry cleaning

**Heat transfer fluid**
- refrigeration
- supercritical power system

**Other**
- food and beverages
- welding
- medical uses
Examples of CCU without capture installation

1. Production of algaees
   • Exhaust gases (with 20 – 30% CO\textsubscript{2}) are pumped through water with algaees
   • Products: biodiesel and similar
   • Energy needed
     - Sunlight (renewable) for algaees growth
     - Electrical energy for pumps

2. Use of microbes (Oakbio)
   • Exhaust gases (with 20 – 30% CO\textsubscript{2}) brought to bioreactor
   • Microbes convert CO\textsubscript{2} and hydrogen to new products: plastics, chemicals
   • Electrical energy needed:
     - Hydrogen production:
     - Bioreaction
     - Pumps, etc.

3. Etc.
1. In concrete cement particles continue to react with CO$_2$ (and water) for ever..... But with also continuously decreasing speed
   - This natural recarbonation can be used in cement and concrete production to enhance hardening of concrete or increase early strength (e.g. CarbonCure)
   - Exhaust gases from cement production can be used.
   - Temporary storage of materials increase the effect, e.g. in temporary material dumps.

2. Certain materials (e.g. Olivines and others) can absorb CO$_2$ from the atmosphere or from exhaust gases to form stable products.
   - Faster absorption is possible with higher pressure, and especially higher CO$_2$ concentrations (e.g. after capture and purification of CO$_2$ in a cement plant).
1. Direct use of exhaust gas without real capture and purification
   • Use exhaust gases for algaes / microbes production → biodiesel, Sunfire, Oakbio, etc.

2. Capture in separate installation
   • Amines, membranes, chilled ammonia followed by purification unit

3. Capture in semi-integrated installation
   • Oxyfuel process
   • Direct separation process (e.g. Leilac) followed by purification unit

Preparation of the CO₂ for use
1. Increase concrete recarbonation is possible with higher pressures and/or higher CO$_2$ concentrations in industrial installations.
   1. Use of captured CO$_2$ from cement plants.
   2. Use in cement or concrete production.

2. Industrial installations can increase absorption of CO$_2$ in mineralization processes.
Complex set of possibilities of CCU including capture

\[
\text{CO}_2 + \text{H}_2 \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6
\]

\[
\text{CO}_2 + \text{H}_2 \xrightarrow{\text{sunlight}} \text{CH}_4 \quad \text{H}_2\text{O} \quad \text{CH}_3\text{OH}
\]

\[
\text{CO}_2 + \text{CaO} \rightarrow \text{CaCO}_3
\]
4. Scenarios results – 70% CCS 30% CCU case

- In 2030, the total specific energy consumption reduces 0.4%, when compared to the baseline for 2020. This reduction is mainly due to the fact that the cement process becomes more efficient in 2030 and the CCU process is less relevant than CCS in this scenario.

- For 2050, the total specific energy demand is 66% higher than the baseline for 2020.

- In 2050, CCU methanol represents 87% of the total additional energy needed for CCUS technologies implementation.

- Among the CCS technologies, oxyfuel represents 60% of the energy consumption.

- The electricity consumption increases from 0.4 GJ/t cement (2020) to around 3.2 GJ/t cement in 2050. The electrolysis alone represents 81% of the electricity demand.
Will there be a need for industrial CO₂ in an intermediate period and how long will this take?

**Industrial point sources**
25% can meet the demand till 2050 for:
- Total CO₂ carbon, in combination with biogenic/DAC sources.
- CCU fuels

**Biogenic sources**
Can meet the total demand in 2030, for CCU fuels in 2040, *if biogenic sources are available in a large extent.*
Not in 2050

**DAC**
Insufficient DAC deployment already by 2030.

- CCS primary use case
- CCU as complement if access to CO₂ storage is hampered.
- Mineralization of CO₂: economic potential, while enables negative emissions,
- Biogenic CO₂ sources (biofuel production): low-cost recovery
- DAC decentral CCU applications (Power-to-X value chains)
1. 87 Projects listed.

2. 8 Projects eligible for funding by EU ETS) Innovation Fund for large scale projects

3. Projects covering all 5Cs, main focus
   1. CCS
   2. CCU
   3. New cements, new clinkers
1. Climate change as top priority will not move away
   1. Cement and concrete industry are clearly in focus
   2. Carbon neutrality is not a question anymore: We have to achieve in 2050

2. Carbon capture is one of fundaments for carbon neutrality
   1. For 2050 in CEMBUREAU roadmap estimated at 42% of emissions
   2. Main part of captured CO$_2$ for geological storage
   3. Significant part of captured CO$_2$ for use and reuse
   4. Recarbonation of concrete and mineralization of materials will become important.

3. Renewable energy supply is fundamental for carbon neutrality
   1. Doubling energy demand for CCS
   2. Tripling energy demand for some CCU processes

4. Industrial CO$_2$ as feedstock in the future: cement is best!