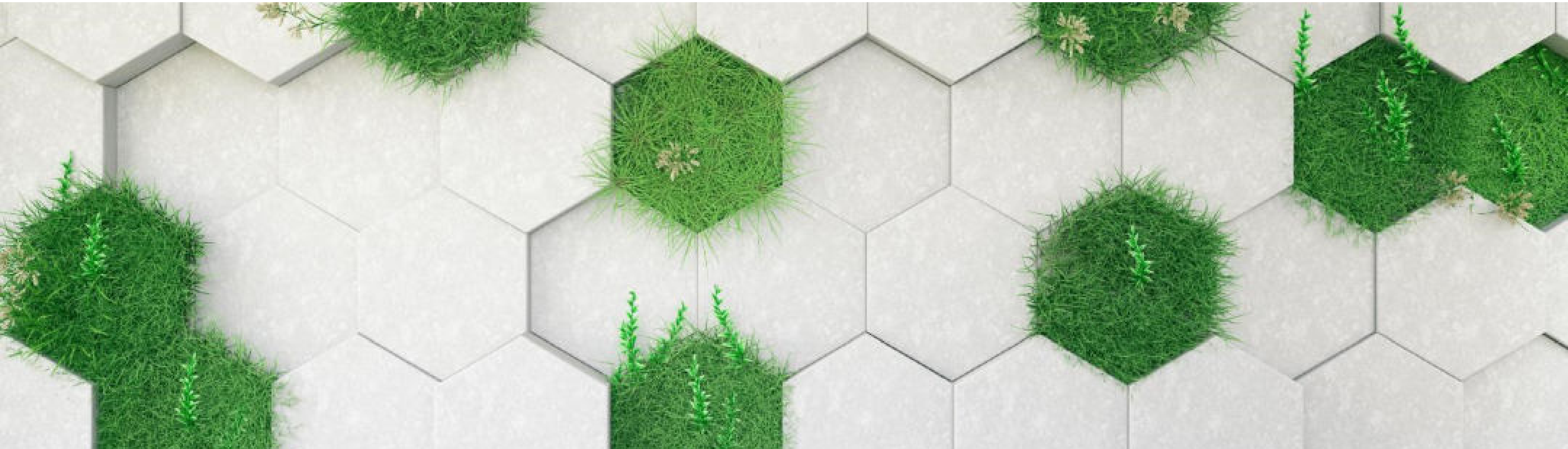
CEMBUREAU
The European Cement Association

BIBM
29 September 2023

CARBON CAPTURE IN CEMENT INDUSTRY

Rob van der Meer



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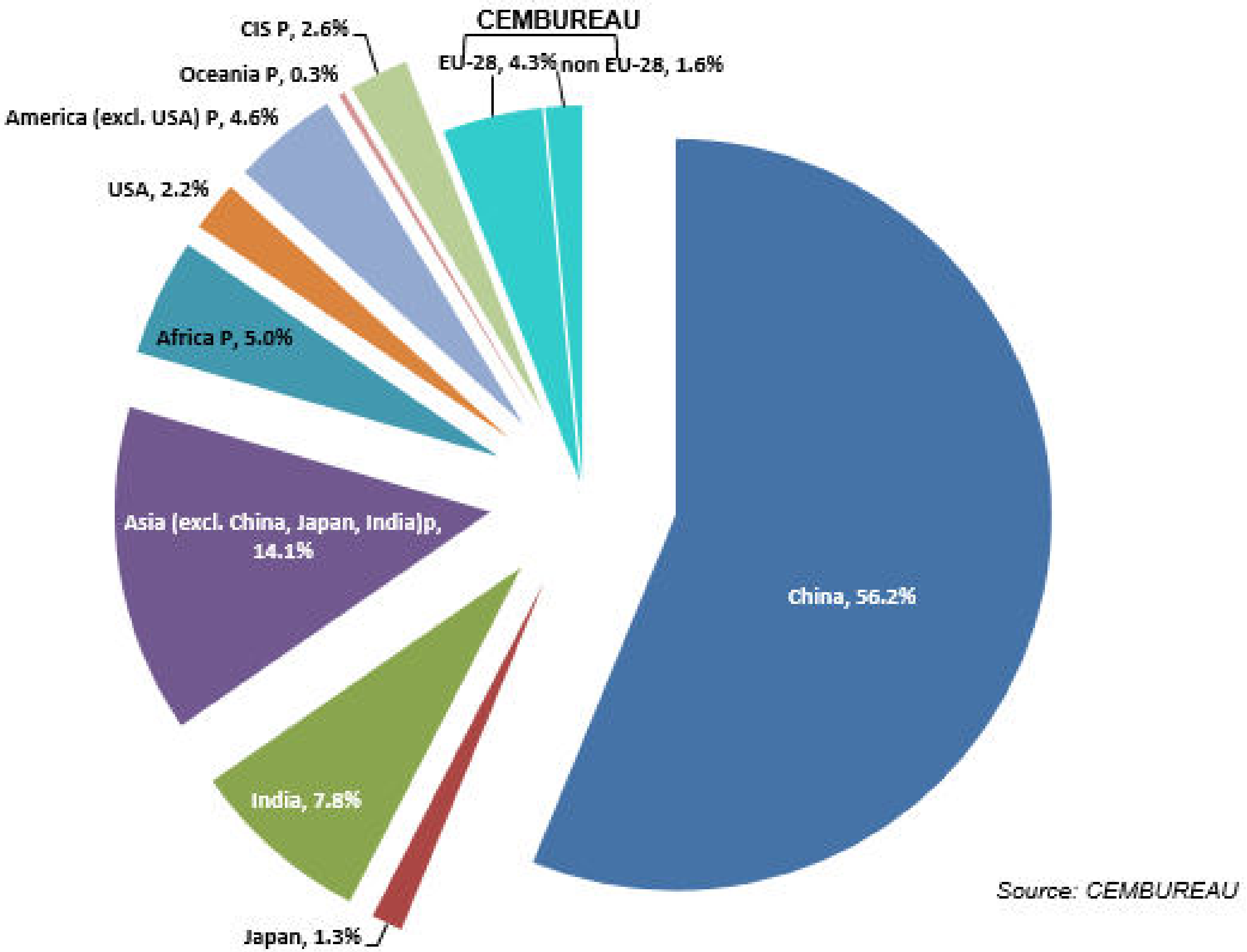
World Cement Production 2019: 4.1 bn Tonnes

World cement production 2019, by region and main countries, % Estimations



World volume oscillating since few years around 4 mio T

Top 3: China, India, rest of Asia

Source: *CEMBUREAU, Activity Report 2020*

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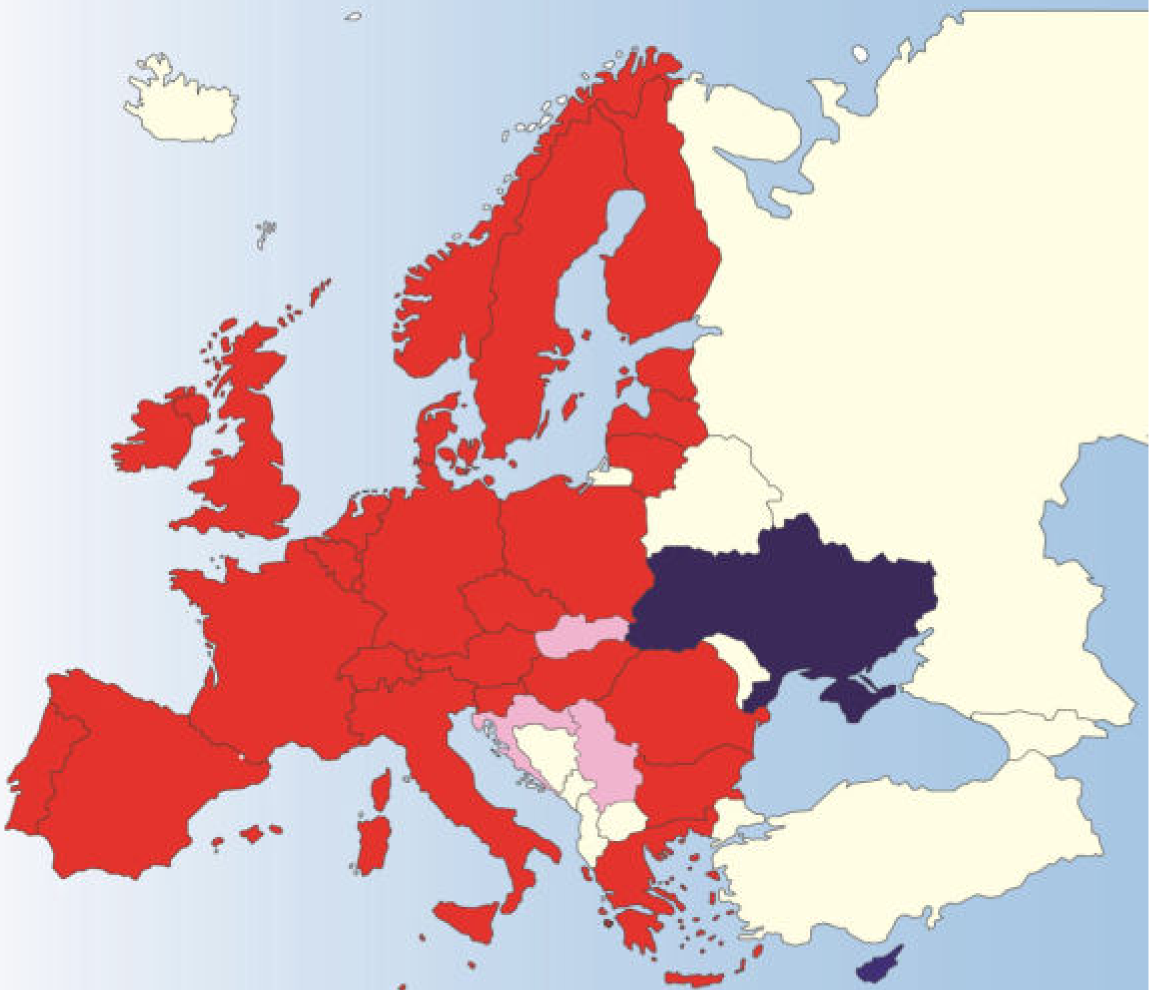


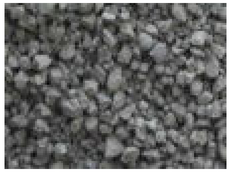
Today: 29 Members
(26 full Members and
3 Associate Members)

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

limestone grinding

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

SUSTAINABLE TRANSPORT

RENEWABLE ENERGY

THERMAL MASS

Trends / Some challenges

- ✓ If we do not act, change will come from <u>outside</u>
  - 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 Grean Deal

GREEN DEAL REQUIRES FROM INDUSTRY

… significant investments

… workforce transformation

… there is more than climate

ENERGY

- ✓ Impact on cost basis
- ✓ Strong renewables development

	solar	wind
2022	206 GW	203 GW
2030	592 GW	510 GW
annual increase	48 GW	36 GW

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

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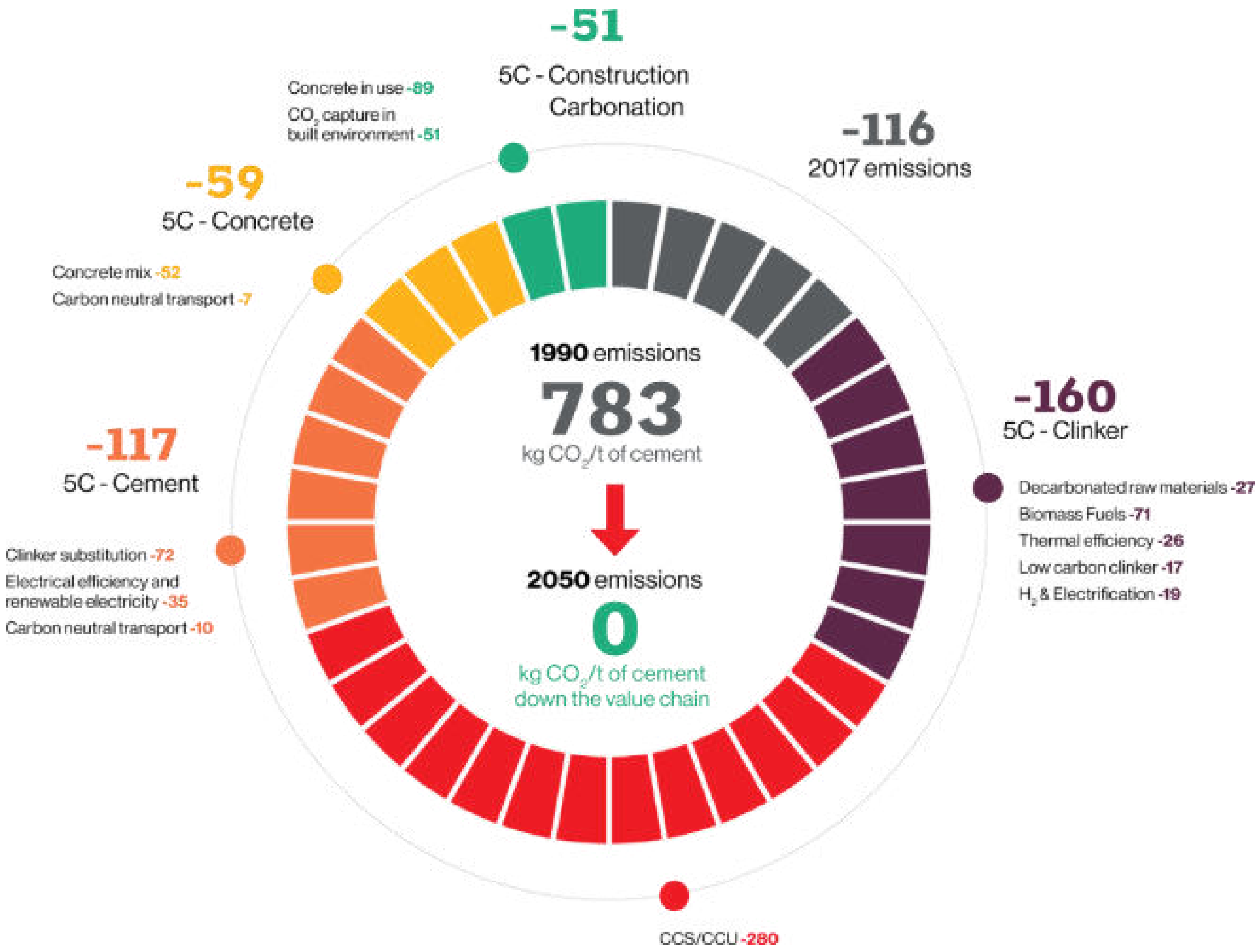
CEMBUREAU’S RESPONSE THE 5C APPROACH

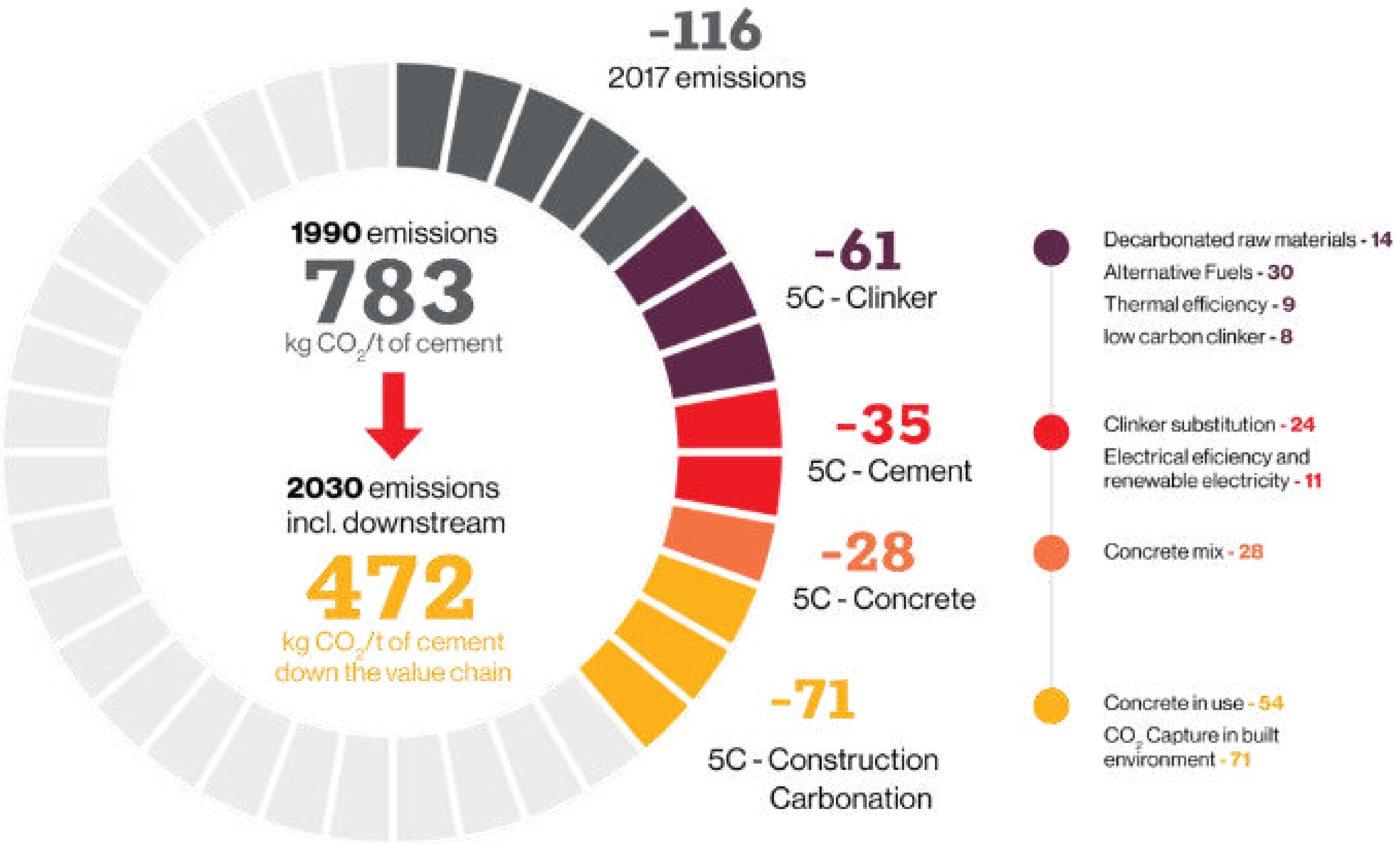
CLINKER
CEMENT
CONCRETE
CONSTRUCTION
CARBONATION

CEMBUREAU 2050 roadmap



CEMBUREAU 2030 roadmap

CO_2 reduction along the cement value chain (5Cs: clinker, cement, concrete, construction, re-carbonation)



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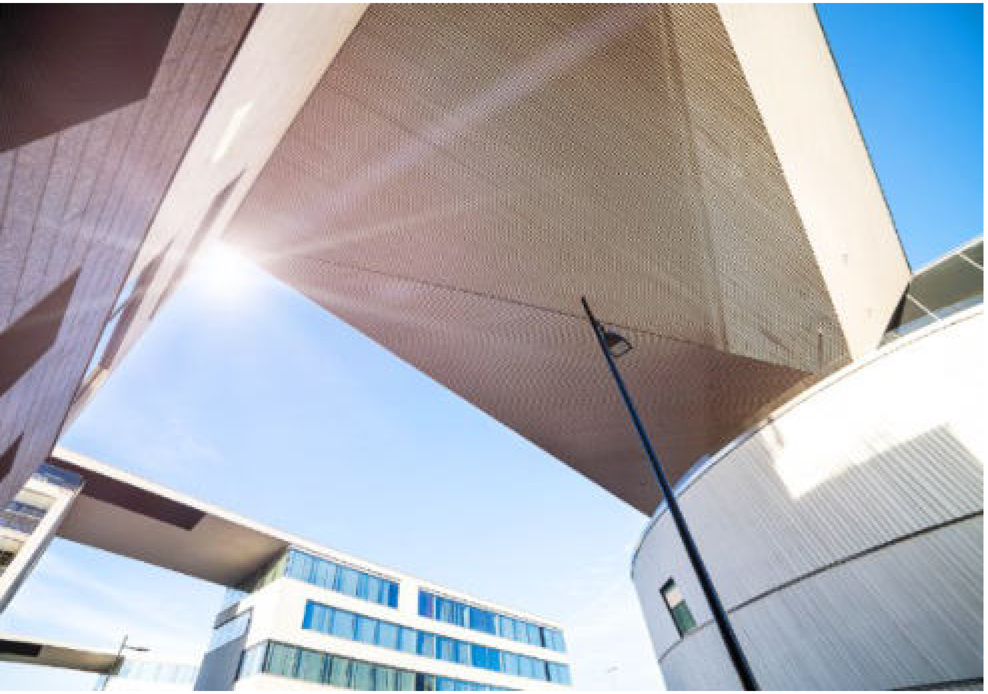


Main Policy Requests

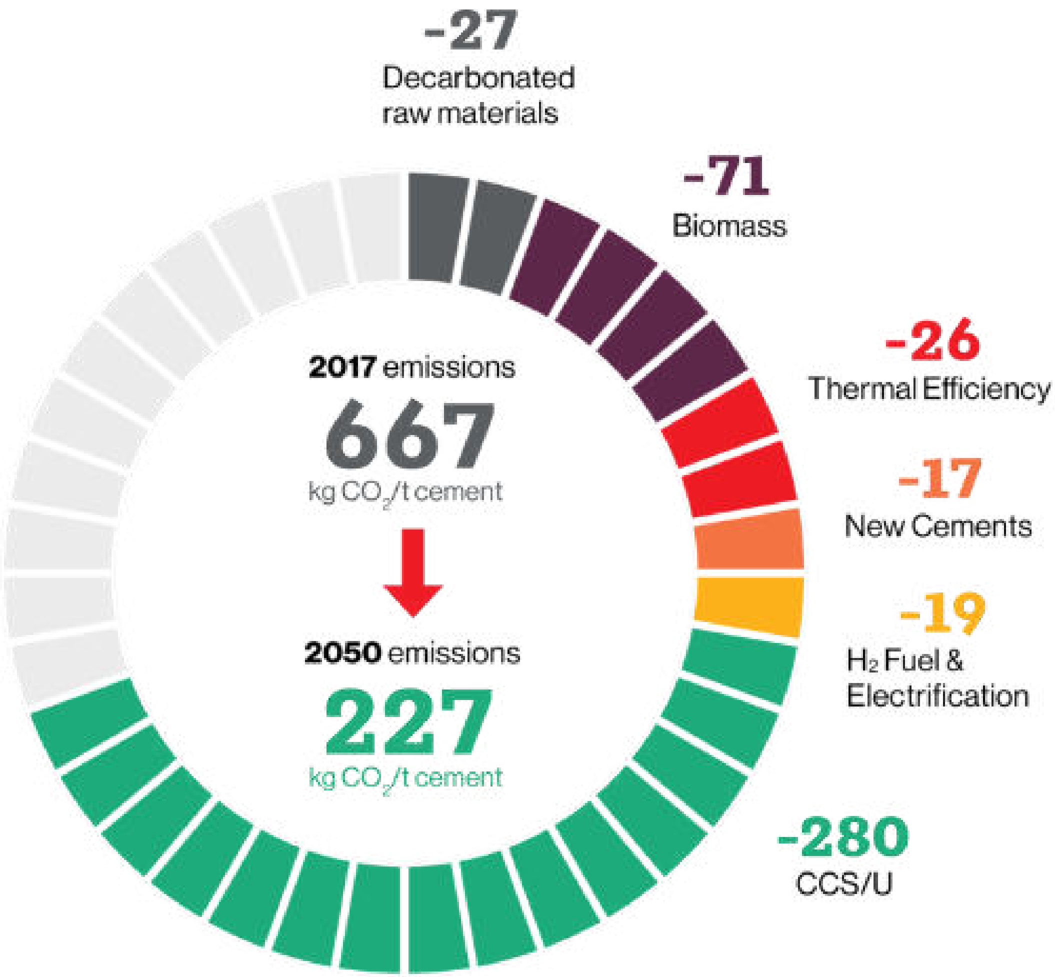
Carbon Capture, Use and Storage (CCUS) will account for **42% of the CO_2 emissions reduction** in the sector. The EU should urgently look at developing a **pan-European CO_2 transportation and storage network,** provide continued **funding to demonstrators** and **support the business case** of the 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



- 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 effcient 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

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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.**

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Abbreviation CCUS

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

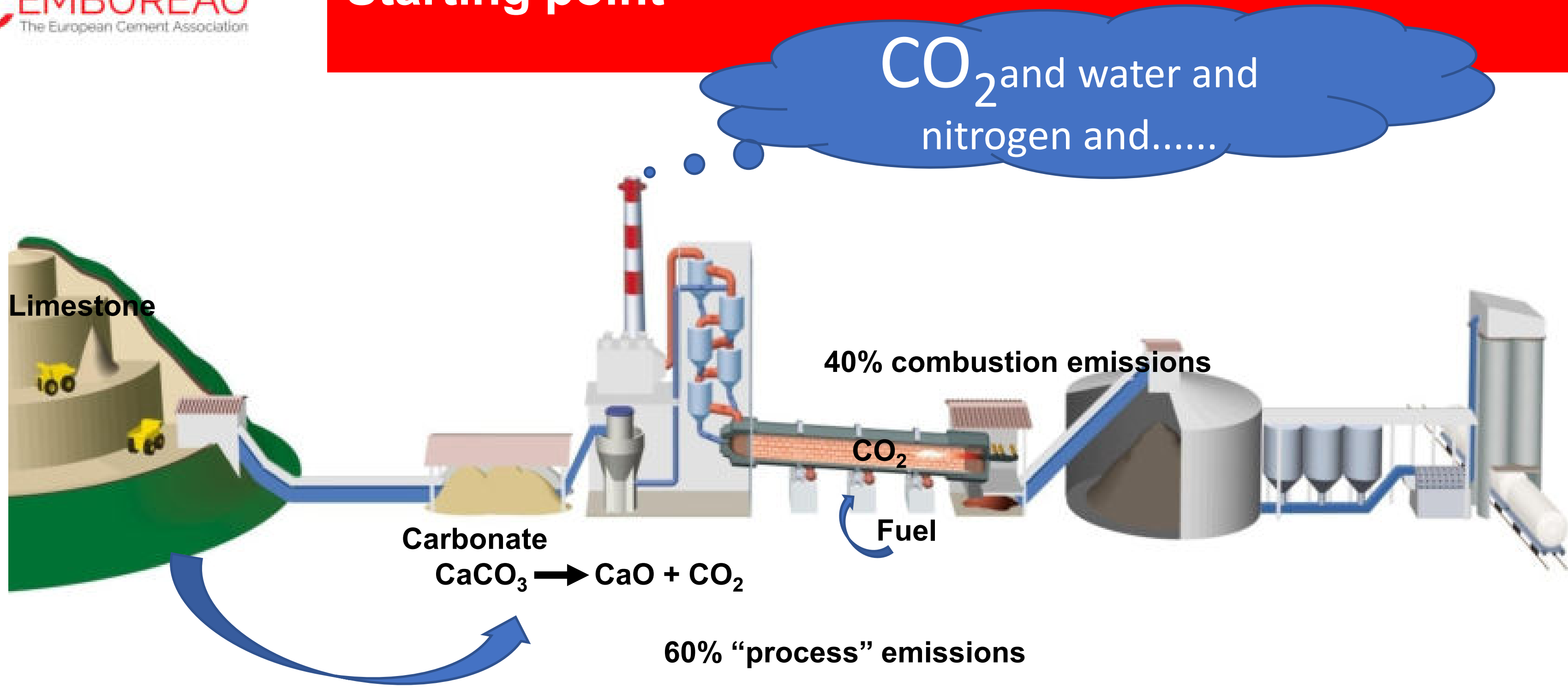
- CCS Carbon Capture and **Something**

Fundamental

Three elements within these abbreviations

1. Carbon Capture
2. Storage
3. Use / reUse / Valorization

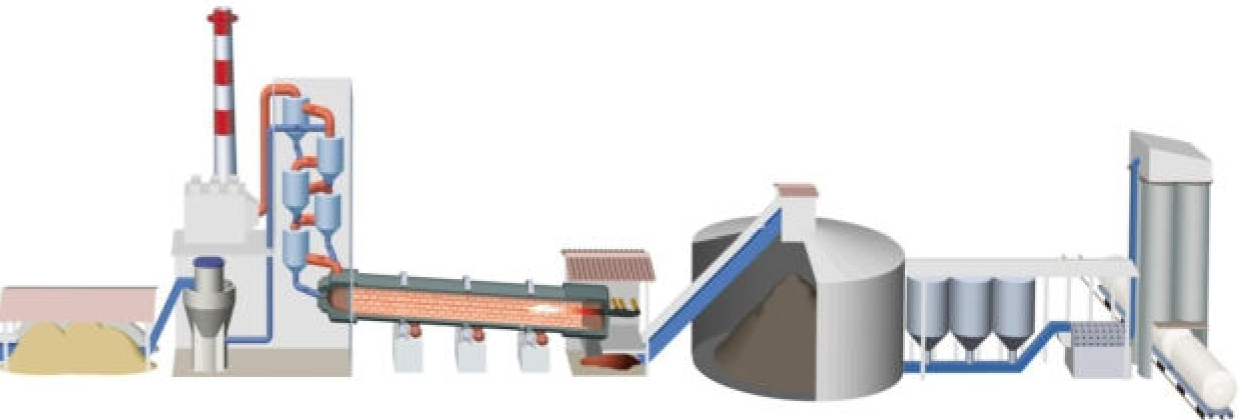
Starting point



- Carbon Capture is about how to capture that CO_2
- Three types of technologies
  1. Pre Combustion Capture — doesn’t make sense in cement
  2. Post Combustion Capture
  3. Oxyfuel Combustion and others

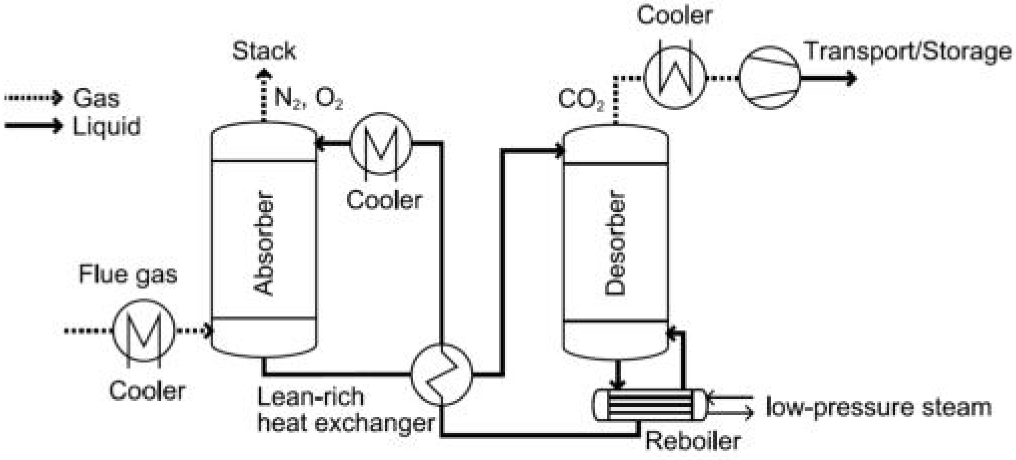
Post Combustion Capture = End of Pipe Technology

capture → Pure CO_2 gas/liquid/solid



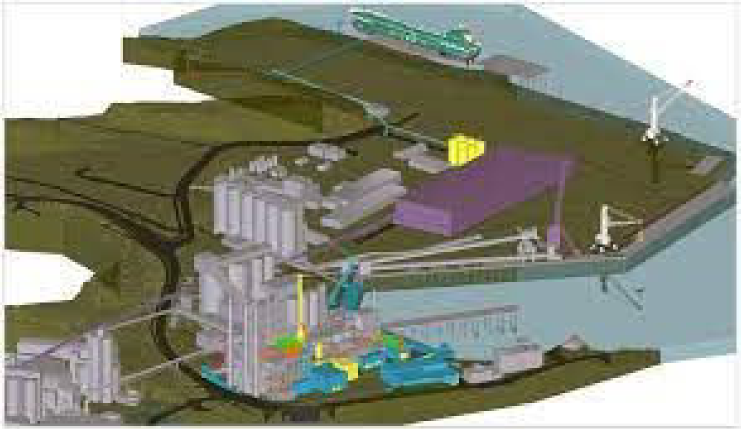
- <u>Typical Post Combustion Capture processes</u>
  - Amine absorption — Technology from 1930, well known in chemicals concept to be used in Brevik, Norway
  - Chilled ammonia — More complicated and challenging
  - Membrane separation — New technologies....... R&D phase
- <u>Oxyfuel and other processes</u>
  - Oxyfuel process — New type of cement production process
  - Direct separation — E.g. Leilac
  - Calcium looping — Too complicated to explain

Amine absorber



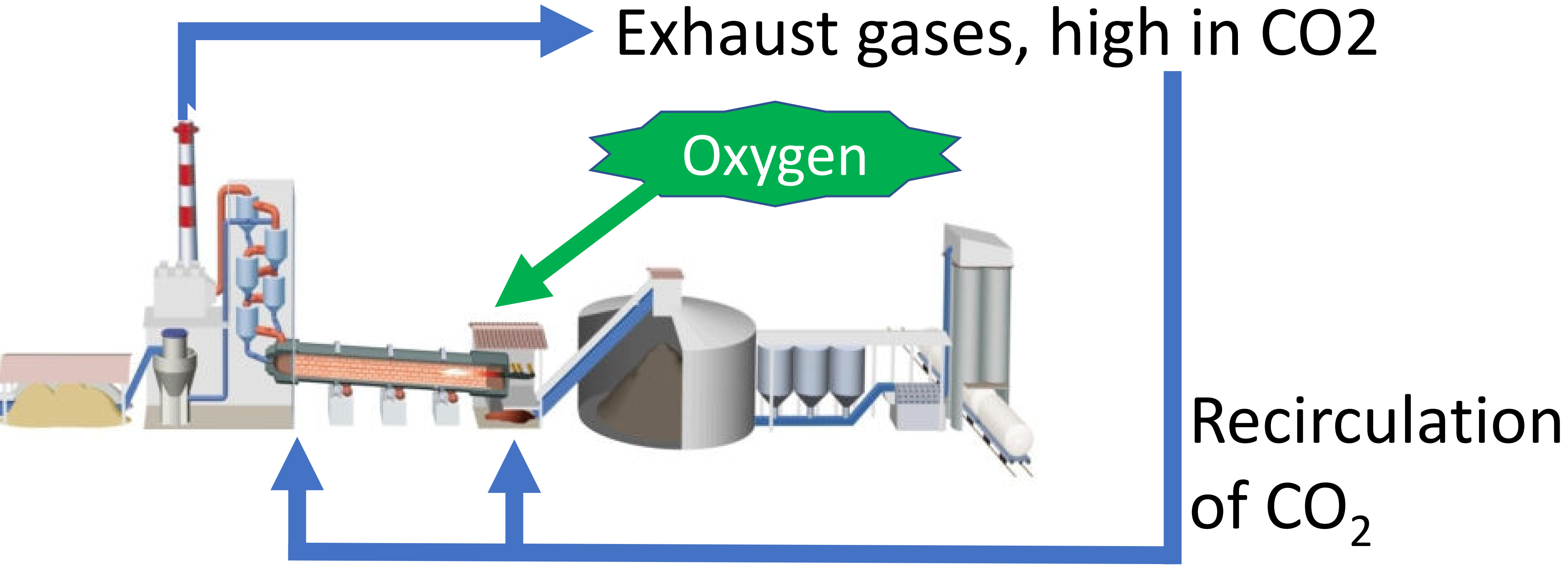
Amine absorption basic design

Test unit in Brevik (2015 – 2018), Norway



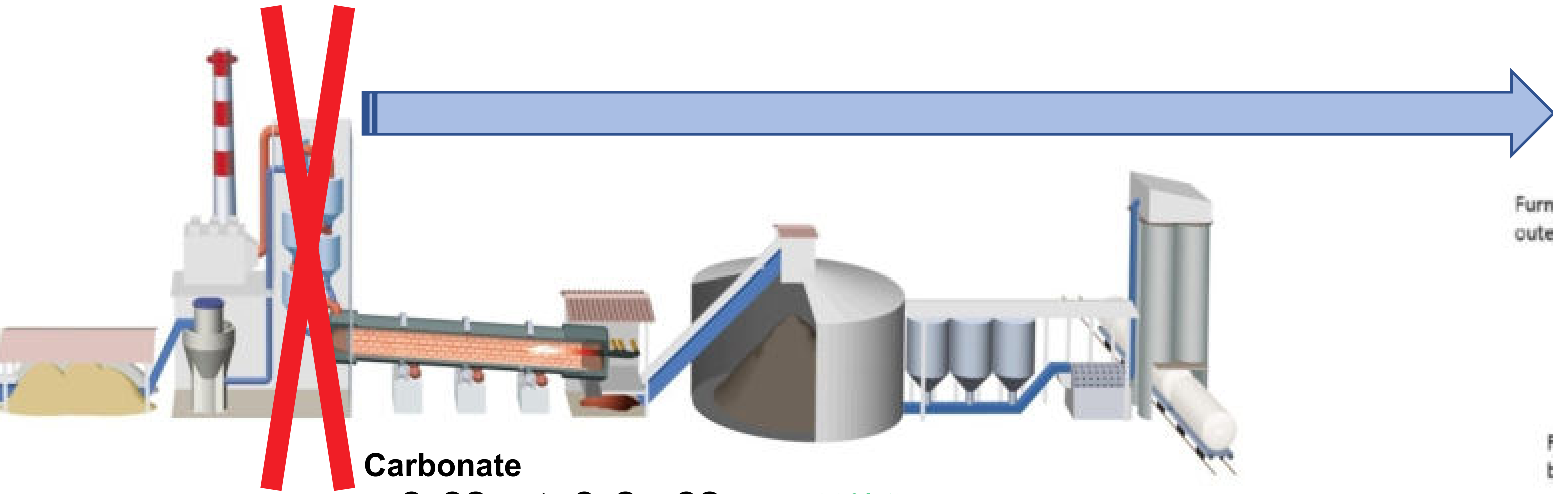
Lay out for demo-scare project in Brevik

Oxyfuel process



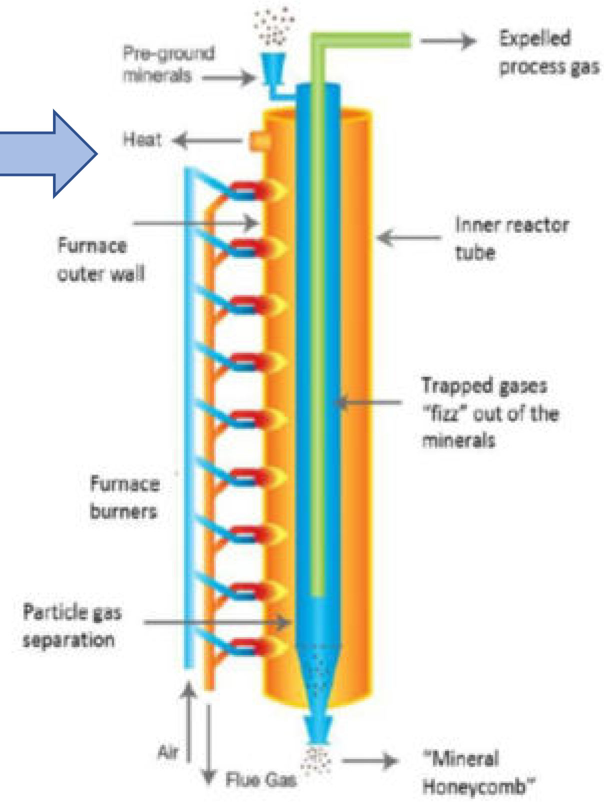
- Research done by ECRA, CemCap (with Sintef)
- Pilot projects / Demo projects planned
  - Westküste 100 = Holcim
  - Catch4Climate = Schwenk, Vicat, Dyckerhoff, HeidelbergCement

Direct separation



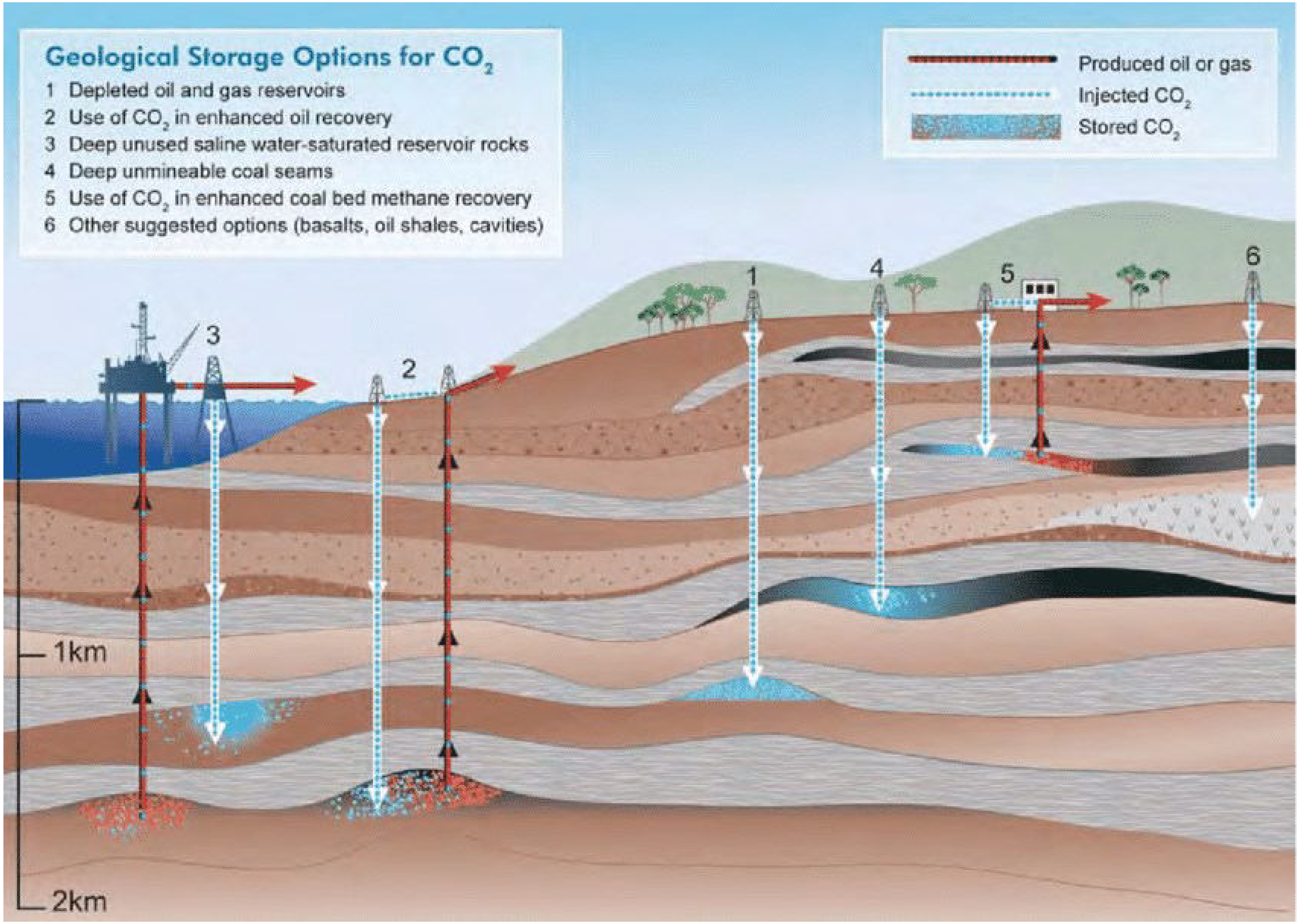
Carbonate
$CaCO_3 \rightarrow CaO + CO_2$

60% “process” emissions

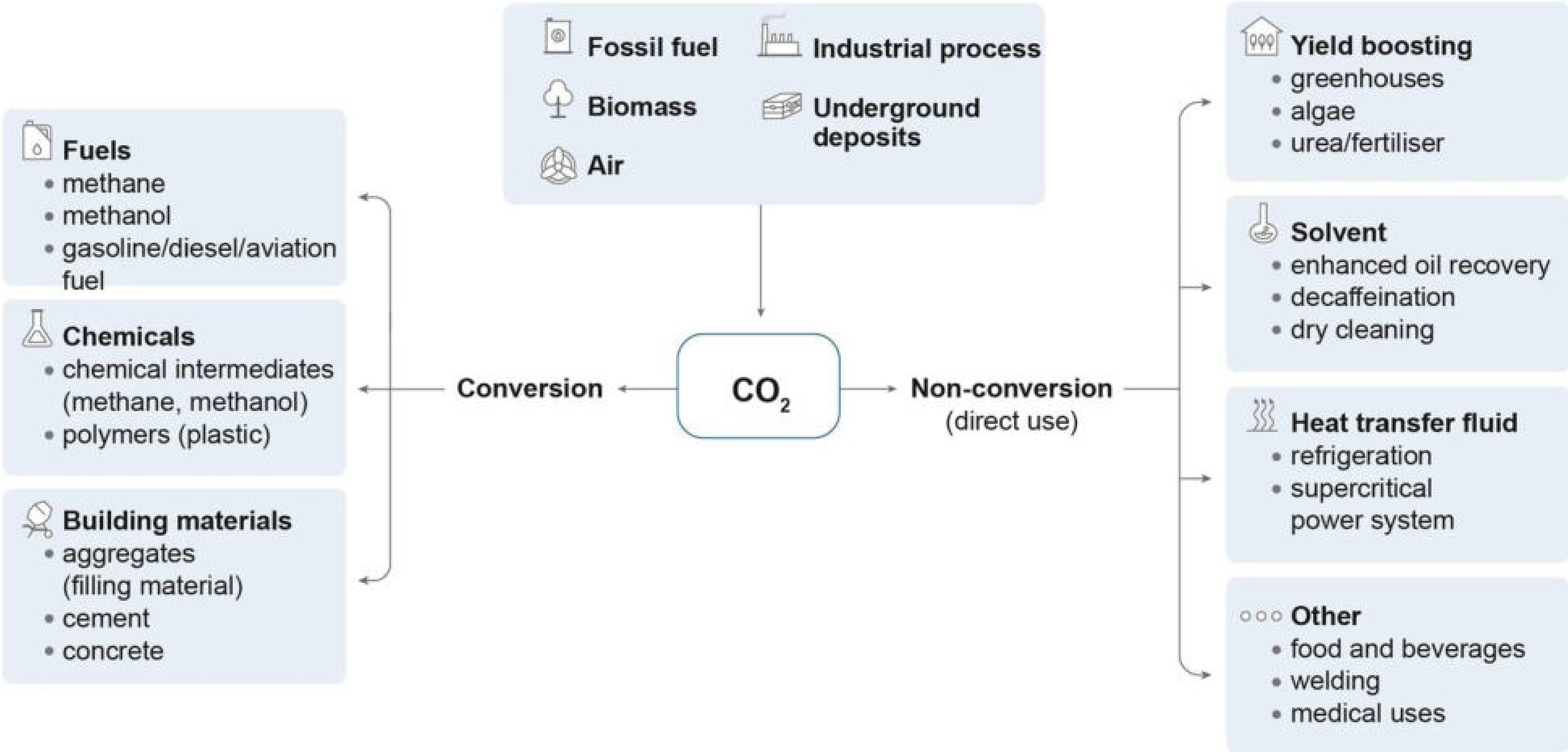


- LeiLac projects in Lixhe (Be) & Hannover
- Split between combustion emissions and process emissions
  - Clean stream of process emissions

Geological Storage

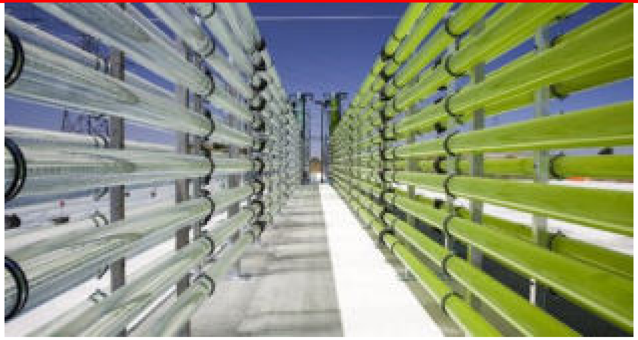


Overview IEA (2021)

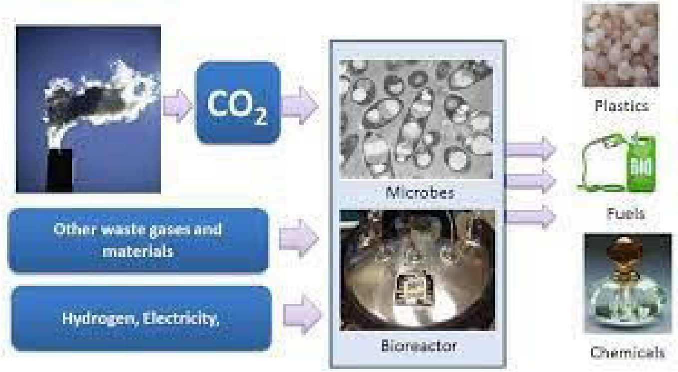


Examples of CCU without capture installation

1. Production of algaes
   - Exhaust gases (with 20 – 30% CO_2) are pumped through water with algaes
   - Products: biodiesel and similar
   - Energy needed
     - Sunlight (renewable) for algaes growth
     - Electrical energy for pumps



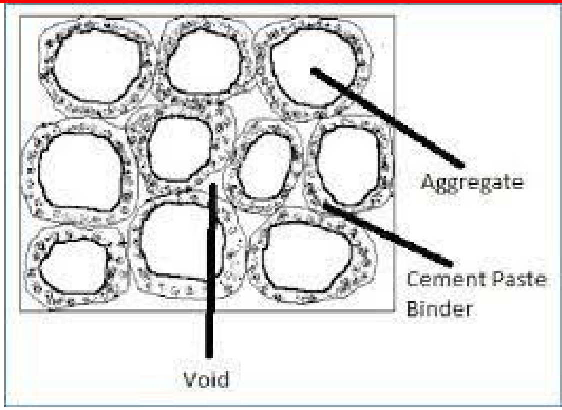
2. Use of microbes (Oakbio)
   - Exhaust gases (with 20 – 30% CO_2) brought to bioreactor
   - Microbes convert CO_2 and hydrogen to new products: plastics, chemicals
   - Electrical energy needed:
     - Hydrogen production:
     - Bioreaction
     - Pumps, etc.

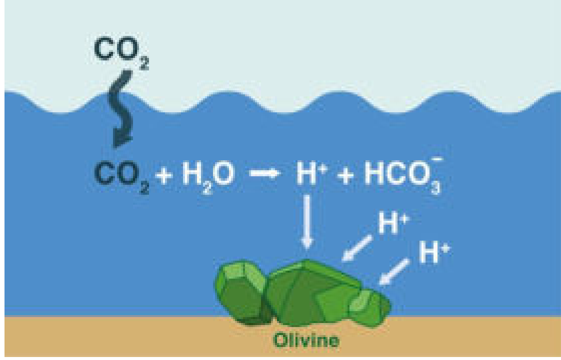


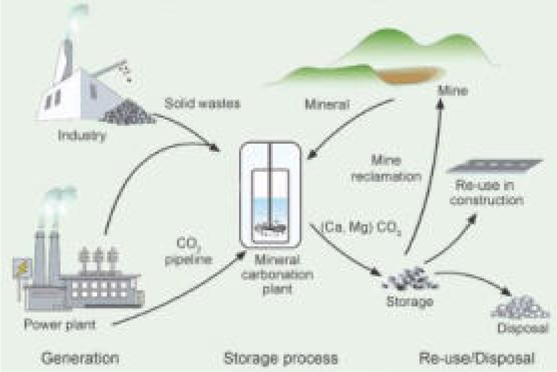
3. Etc.

Mineralisation and recarbonation without capture installation

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 absorp 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).

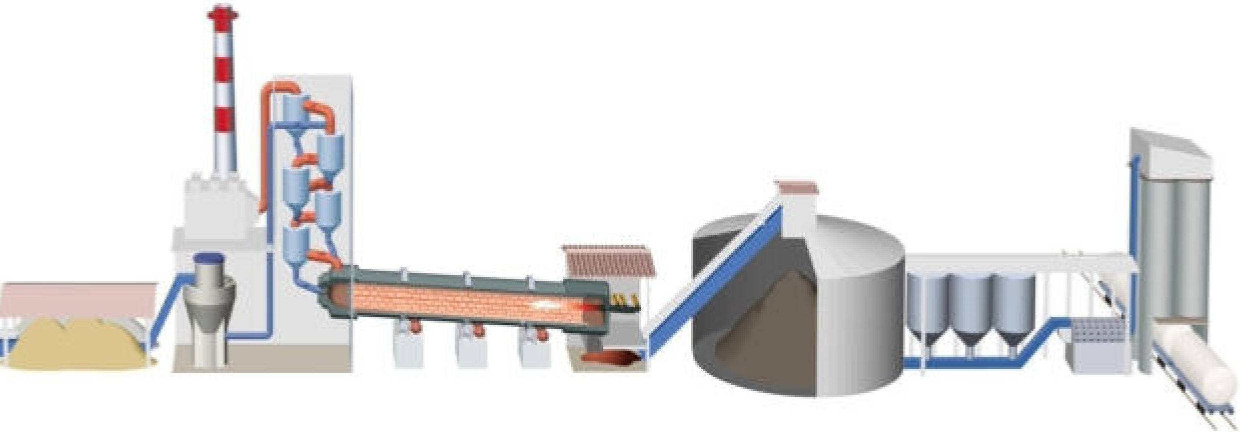






Preparation of the CO_2 for use

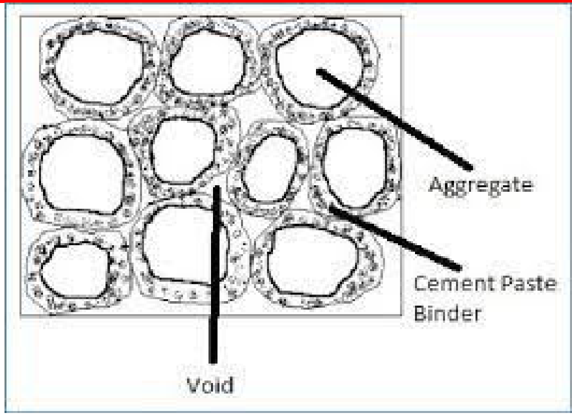
capture → CO_2 gas/liquid/solid



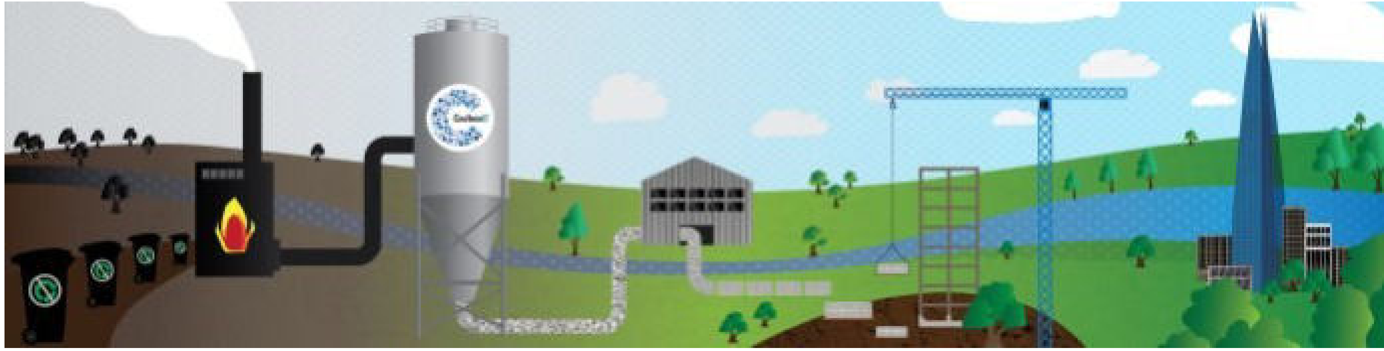
1. Direct use of exhaust gas without real capture and purification
   - Use exhaust gases for algaes / microbes production ⟶ biodiesel, Sunfire, Oakbio, etc.
2. Capture in separate installation
   - Amines, membranes, chilled ammonia followed by purification unit
3. Capture in semi-integrated installation
   - Oxyfuel process
   - Direct separation process (e.g. Leilac) followed by purification unit

Mineralisation and recarbonation with capture installation

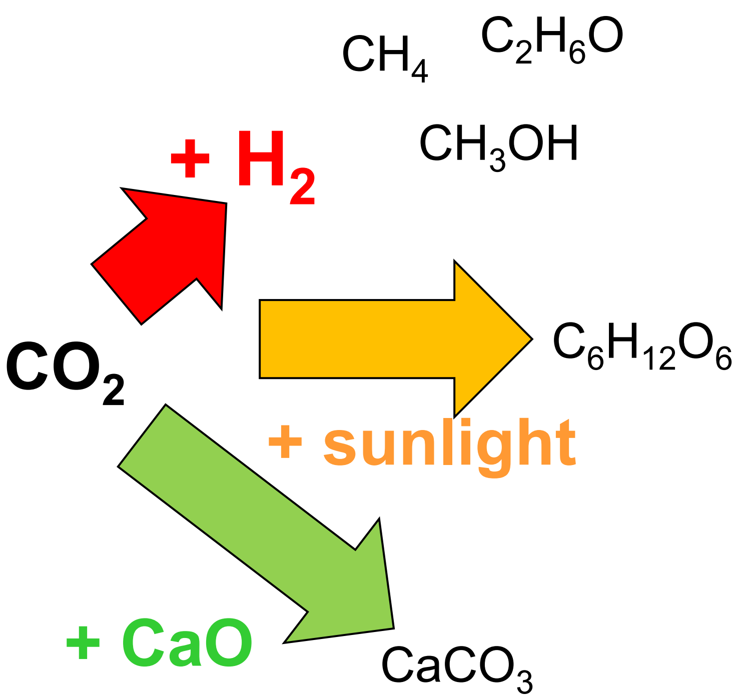
1. Increase concrete recarbonation is possible with higher pressures and / or higher CO_2 concentrations in industrial installations.
   1. Use of captured CO_2 from cement plants.
   2. Use in cement or concrete production.

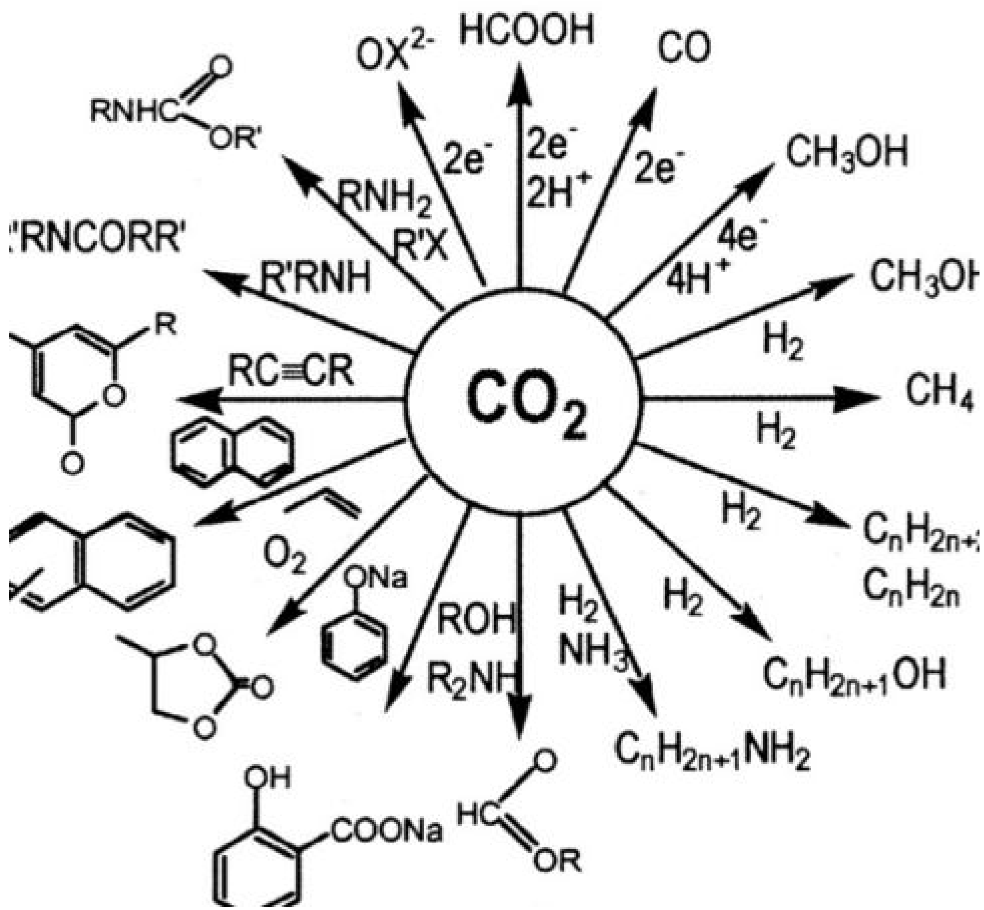


2. Industrial installations can increase absorption of CO_2 in mineralization processes.



Complex set of possibilities of CCU including capture

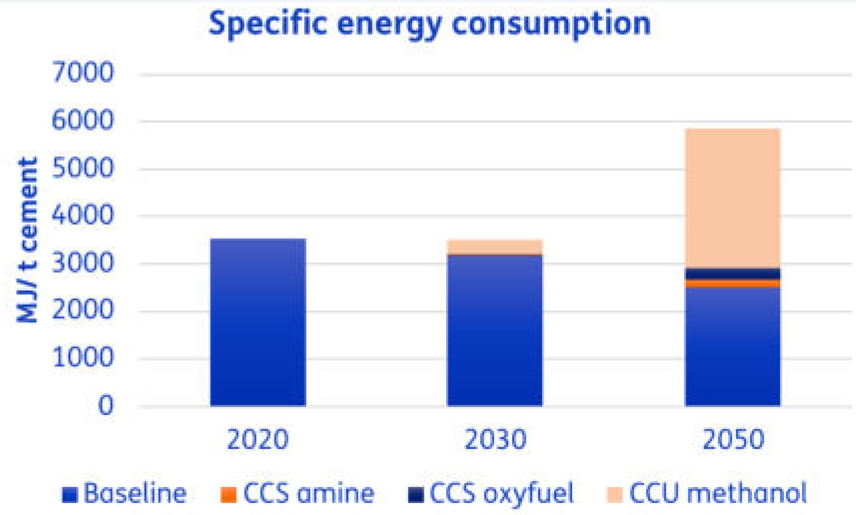


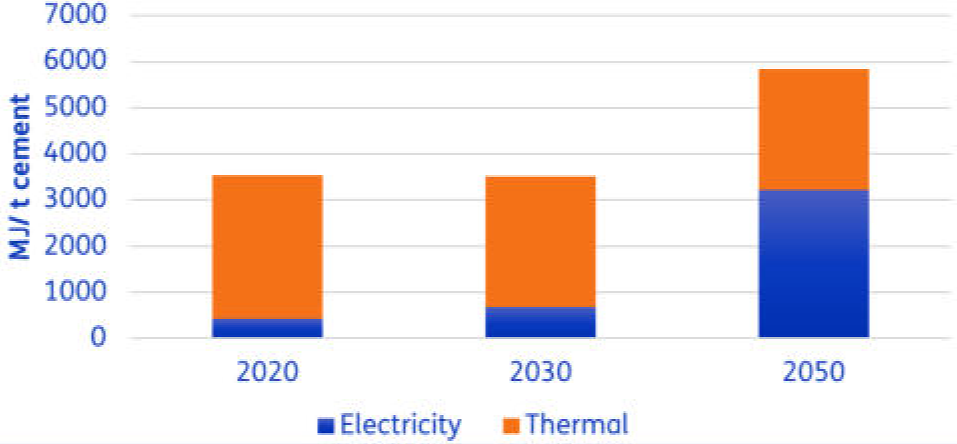


Results for one scenario

EU Cembureau Energy Review Study - EU Cement

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**

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CO_2 as resource: VITO study for CEMBUREAU

Will there be a need for industrial CO_2 in an intermediate period and how long will this take?

Industrial point sources

25 % can meet the demand till 2050 for:

- Total CO_2 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 CO_2 storage is hampered.
- Mineralization of CO_2: economic potential, while enables negative emissions,
- Biogenic CO_2 sources (biofuel production): low-cost recovery
- DAC decentral CCU applications (Power-to-X value chains)

vito

vito.be

CEMBUREAU map of innovation projects (CEMBUREAU website)

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

Conclusions

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!

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