Towards a Circular Carbon Economy for the Construction Sector: The Key Role of Innovation

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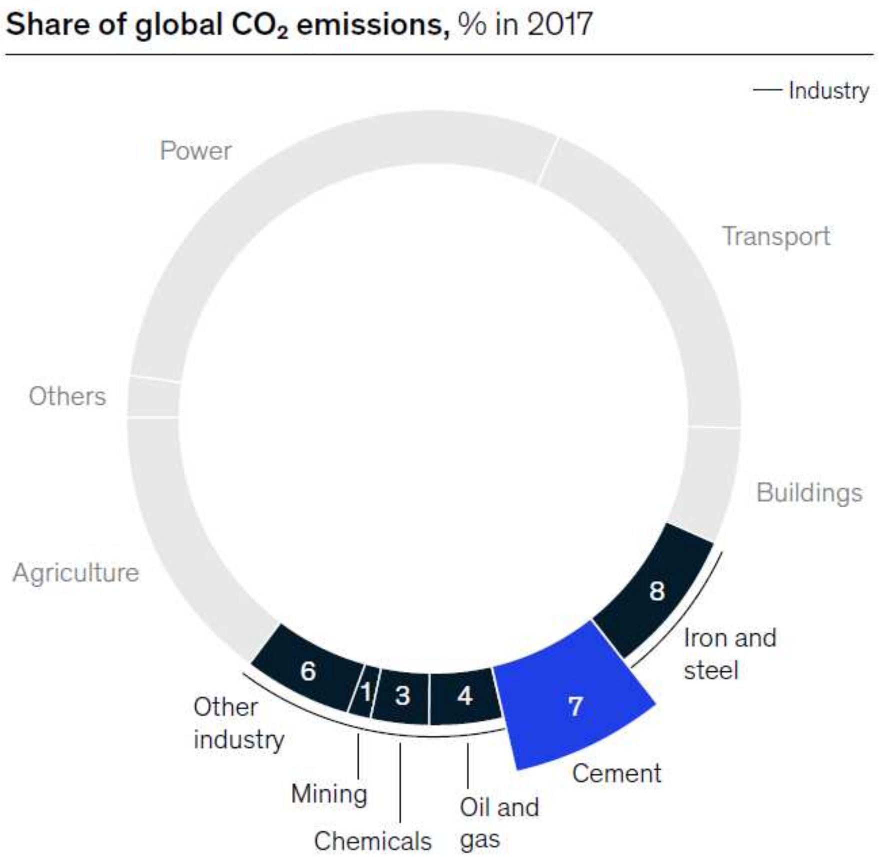
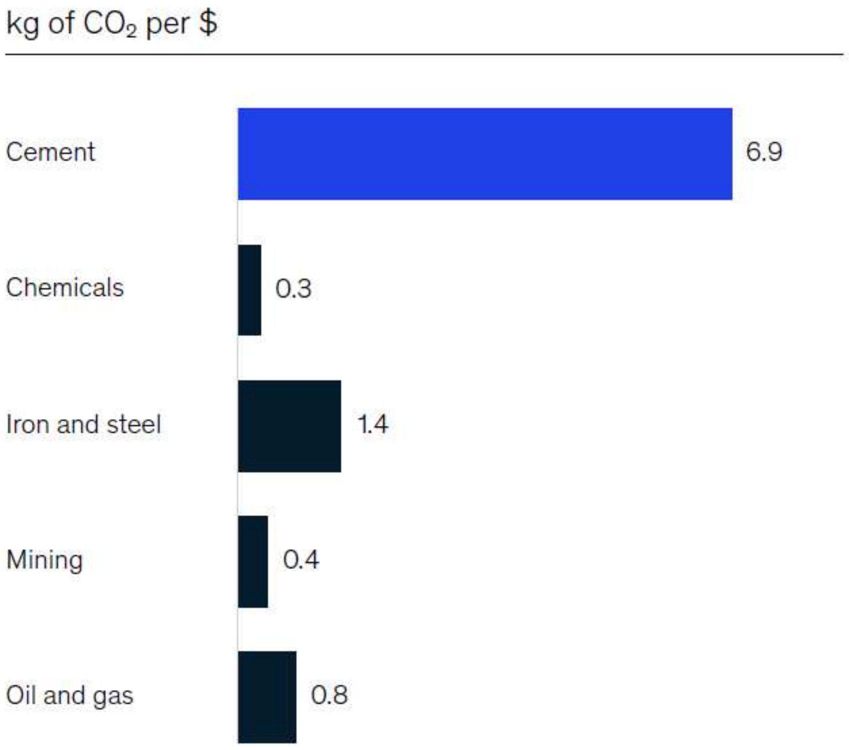
The Carbon Footprint of the Cement Industry

The cement industry is responsible for more than 7% of the total anthropogenic CO_2 emissions and has a carbon footprint of 0.7 kg CO_2 per kg of cement.



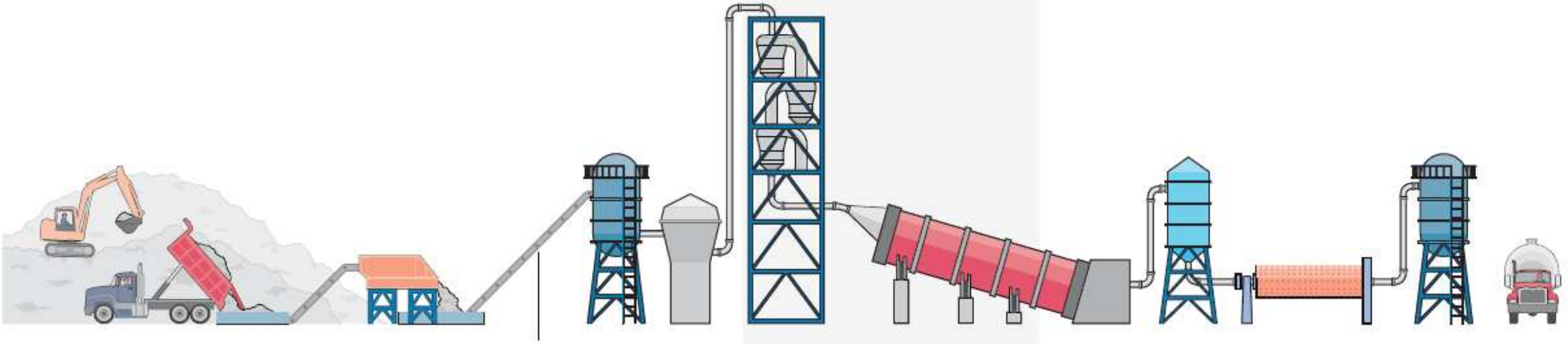


McKinsey & Company (2020) Laying the foundation for zero-carbon cement

The Carbon Footprint of the Cement Industry

CO_2 releases are integral part of the cement making process and cannot be avoided. More than 50% of these are coming from the calcination process.

Raw materials, energy, and resources | **Clinker and cement manufacturing**



	Quarry	Crusher	Transport[1]	Raw mill	Kiln and preheater/ precalcinator[2]	Cooler[3]	Cement mill	Logistics[4]	**Total**
Energy, megajoule/ton	40	5	40	100	3,150	160	285	115	3,895
CO_2, kilogram/ton	3	1	7	17	479 Calcination process; 319 Fossil fuels	28	49	22	925

[1]Assumed with 1kWh/t/100m.
[2]Assumed global average, data from the Global Cement and Concrete Association, Getting the Numbers Right 2017.
[3]Assumed reciprocating grate cooler with 5kWh/t clinker.
[4]Assumed lorry transportation for average 200km.

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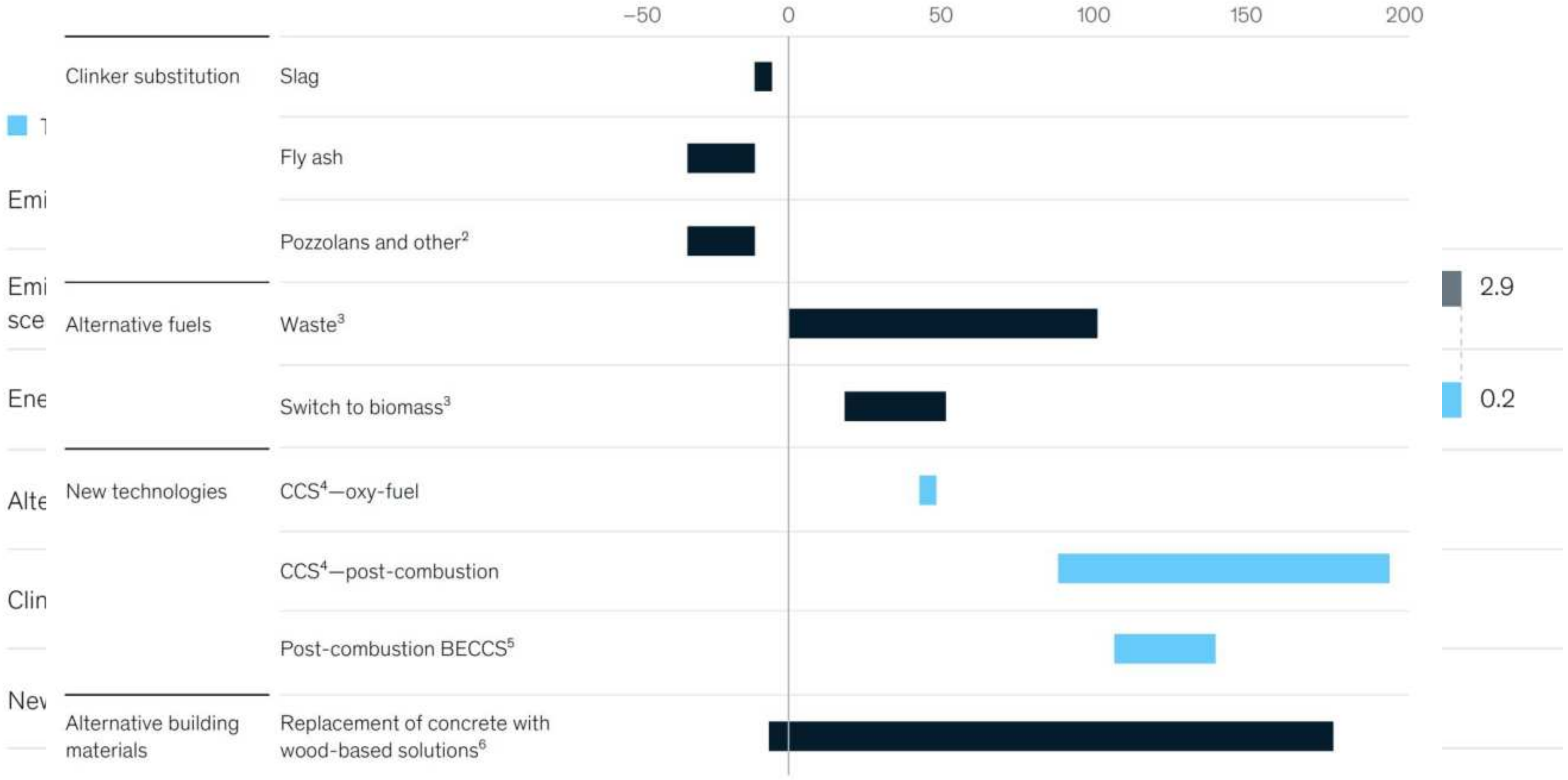
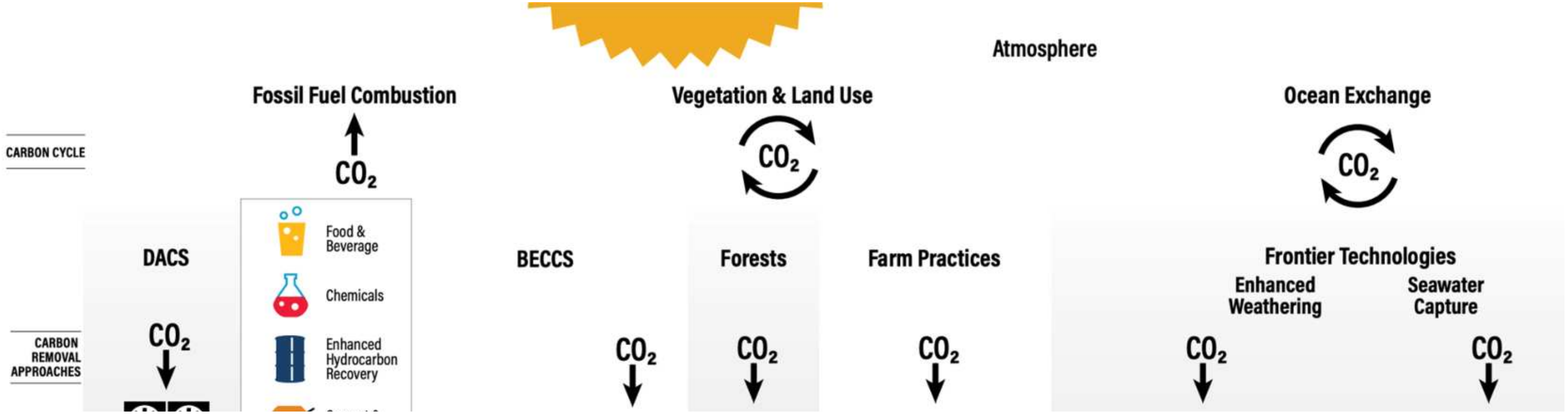


Key role of innovation in reducing the carbon footprint of the cement industry with **Carbon Capture Utilization and Storage (CCUS)** being the most promising option

Carbon Capture Utilization & Storage (CCS)



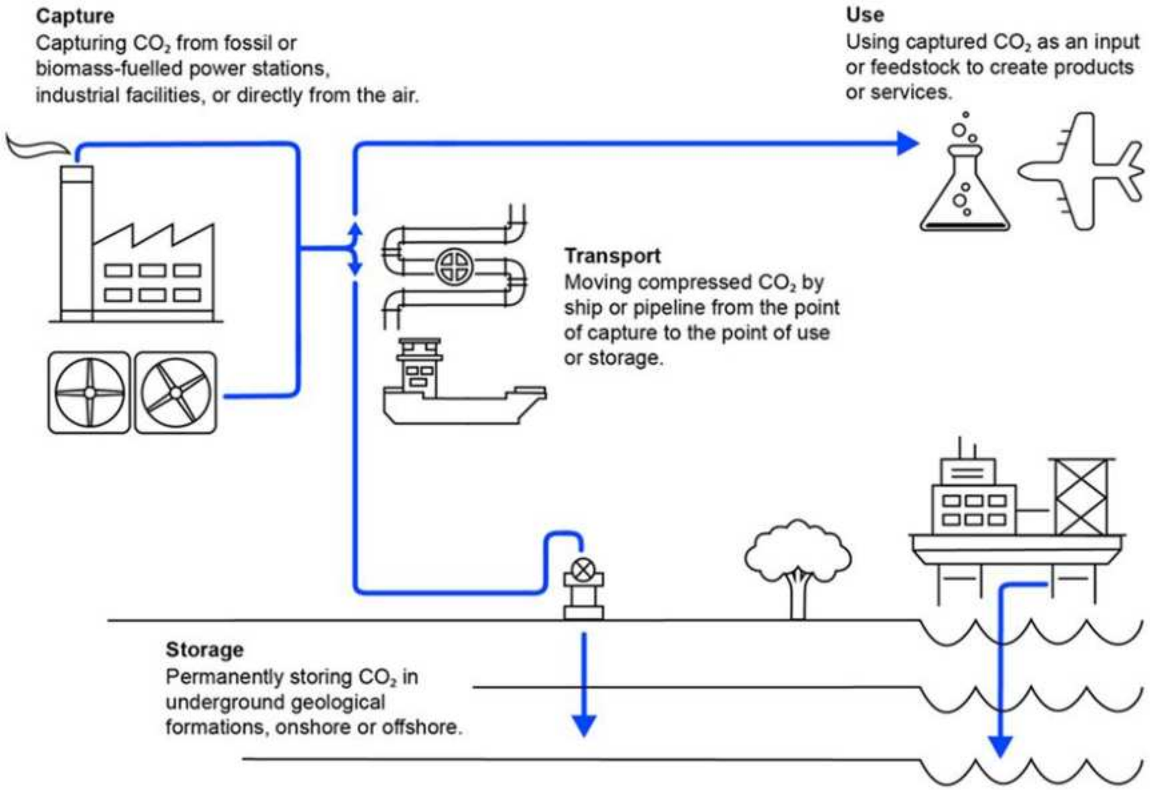
- Carbon Capture Utilization and Storage (CCS) refers to technologies that separate and use captured CO_2 as a feedstock and convert it into value-added products (e.g fuels, chemicals).
- Carbon capture is a key mitigation technology for hard-to-decarbonize industrial sectors (e.g. cement) and heavy-duty long-distance transportation (shipping).
- Carbon is a value-added commodity - CCS focusses on resource efficiency and is aligned with the concept of circular economy Coupled with combustion efficiency improvements and low-carbon fuels can is key for energy transition (particularly in developing countries).
- Bioenergy with carbon capture and storage (BECCS) can lead to net negative emissions (e.g. biogas utilization)

Carbon Capture Utilization & Storage (CCS)

Carbon Capture Utilization and Storage (CCS) refers to technologies that **capture CO_2** from point sources (e.g. power plants, process industries) or directly from air and either **store captured CO_2** in underground geological formations or building materials or use it as a feedstock and **convert** it into **value-added products** (e.g. fuels, chemicals).

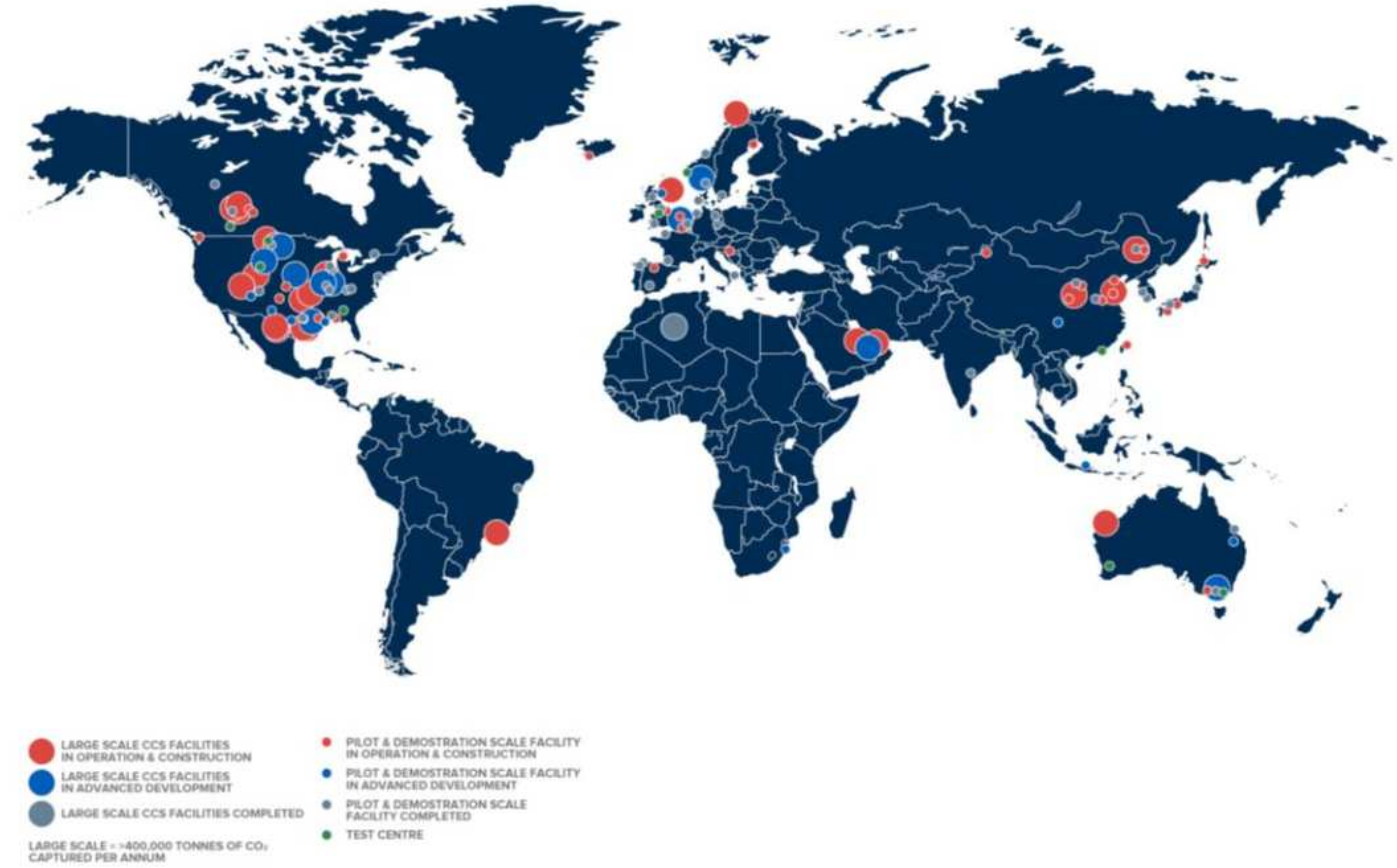
CCS as a decarbonization solution

- Key mitigation technology for hard-to-decarbonize industrial sectors (e.g. cement) and heavy-duty long-distance transportation (shipping).
- Can be retrofitted to existing power and industrial plants and is, to a significant extent, fuel agnostic.
- Can remove CO_2 from the atmosphere by combining it with bioenergy or direct air capture to balance emissions that are unavoidable or technically difficult to abate.
- Enabler of least-cost low-carbon hydrogen production.
- Carbon is a value-added commodity - CCS focusses on resource efficiency and is aligned with the concept of circular economy.
- CCS may be the cheapest and best option for some sectors and sources.



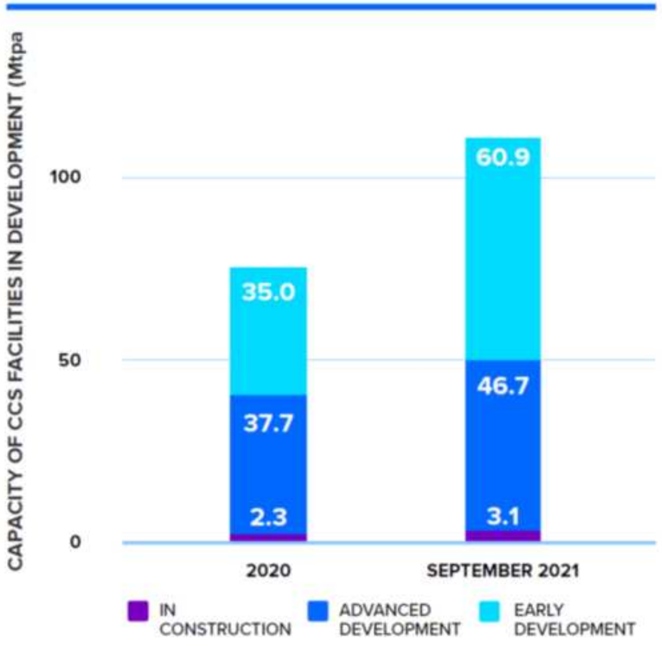
IEA, *Energy Technology Perspectives*, 2020

Carbon Capture Utilization & Storage (CCS)



World CCS in 2021

- ✓ 27 plants operational (2 in Europe)
- ✓ 4 under construction
- ✓ 58 in advanced development
- ✓ 44 in early development



Global CCS Institute. *The Global Status of CCS: 2021*

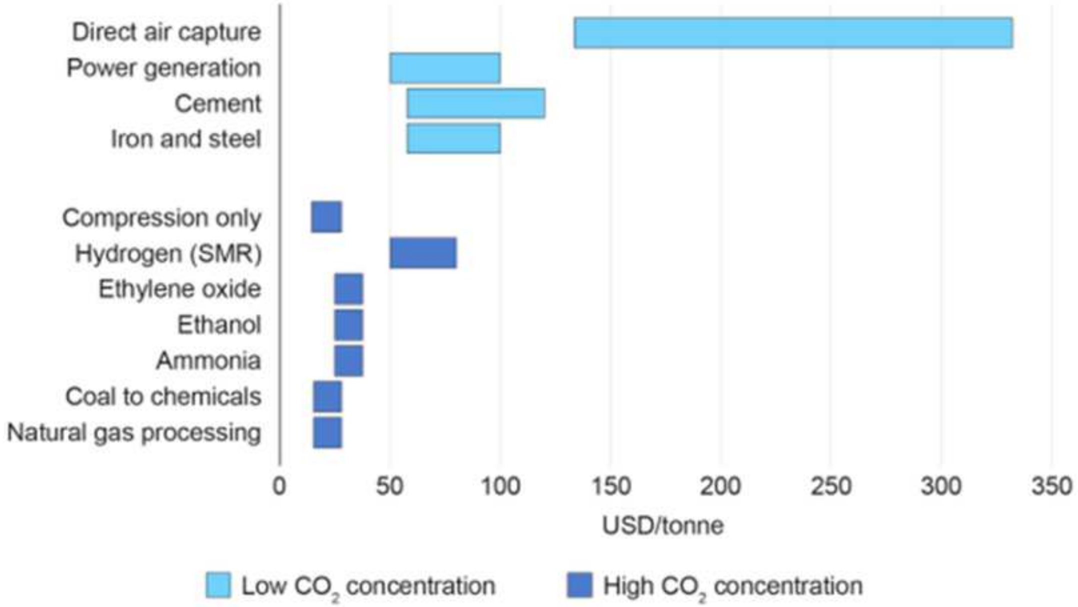
Currently CCS plants in operation and construction have the capacity to capture and permanently store around **40 million tonnes CO_2 per annum (still only 1% of total emissions)**

Carbon Capture Utilization & Storage (CCS)

Carbon capture cost

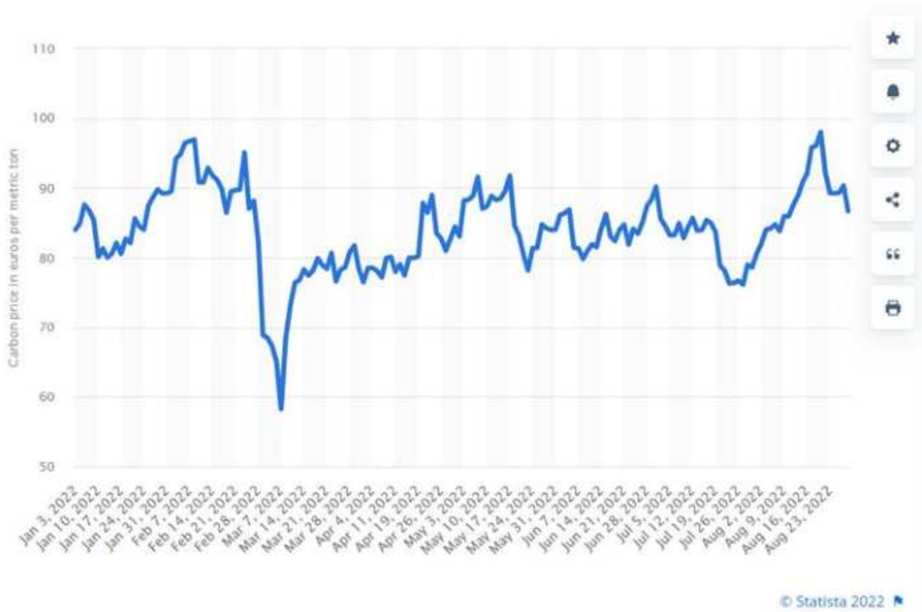
It can vary greatly by CO_2 source from a range of

- **15-25$/t CO_2** for industrial processes producing “pure” or highly concentrated CO_2 streams – *Ethanol or natural gas*
- **40-120$/t CO_2** for processes with “dilute” gas streams - *Cement production and power generation*
- Capturing CO_2 directly from air is currently the most expensive approach but could nonetheless play a unique role in carbon removal



IEA, ETP 2020, *Special Report on Carbon Capture Utilization and Storage*

The cost of CCS has to be compared against the coat of carbon (e.g. EU ETS)



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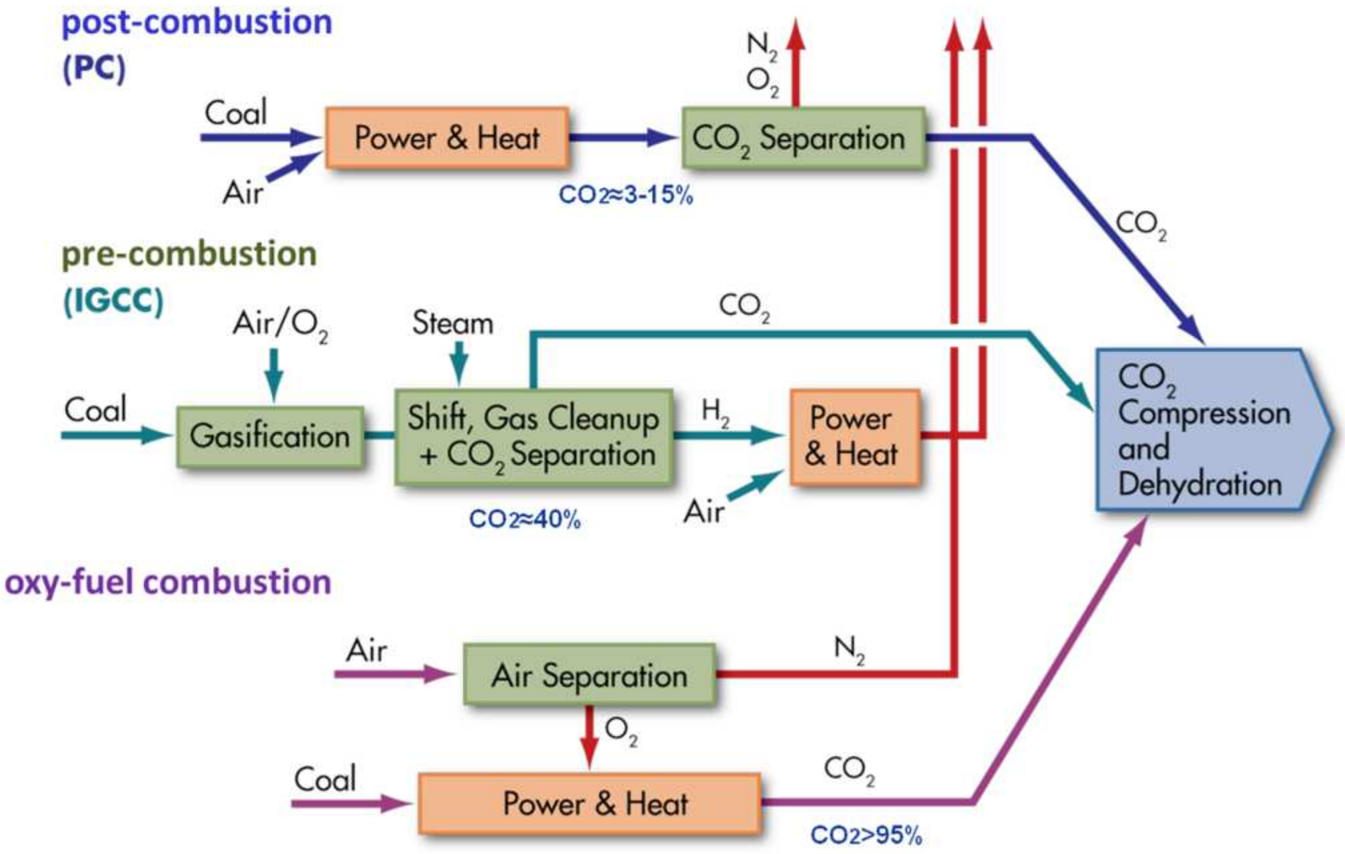

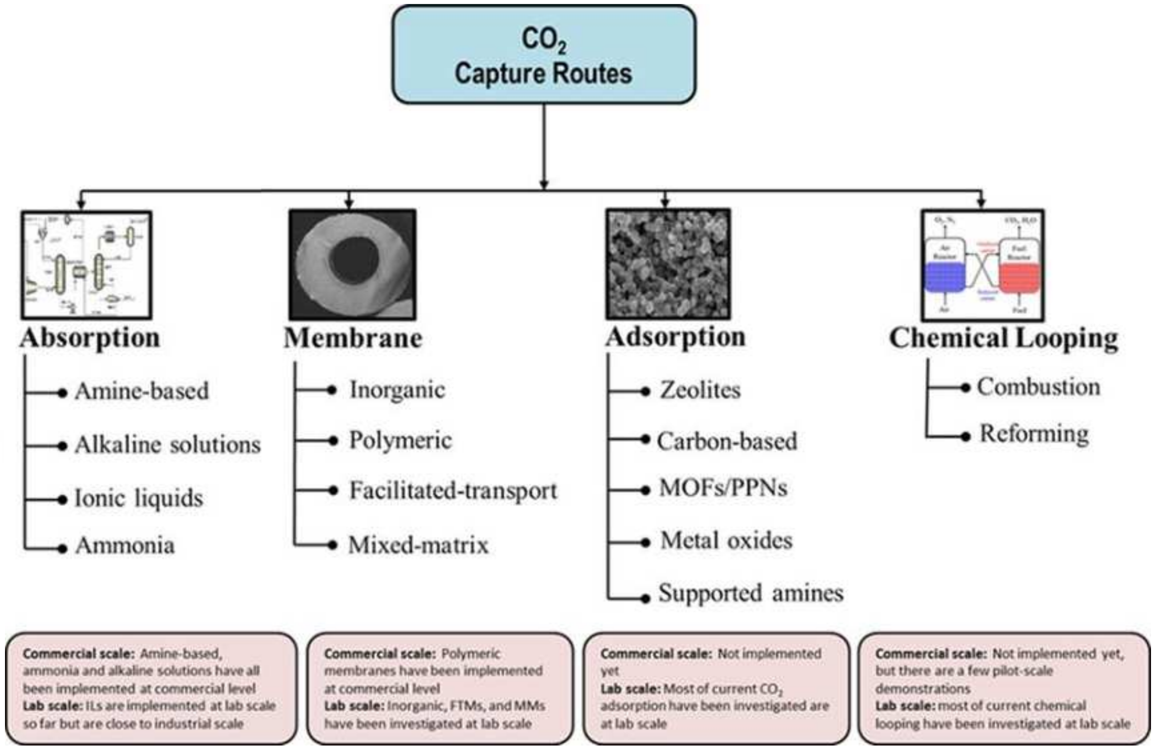

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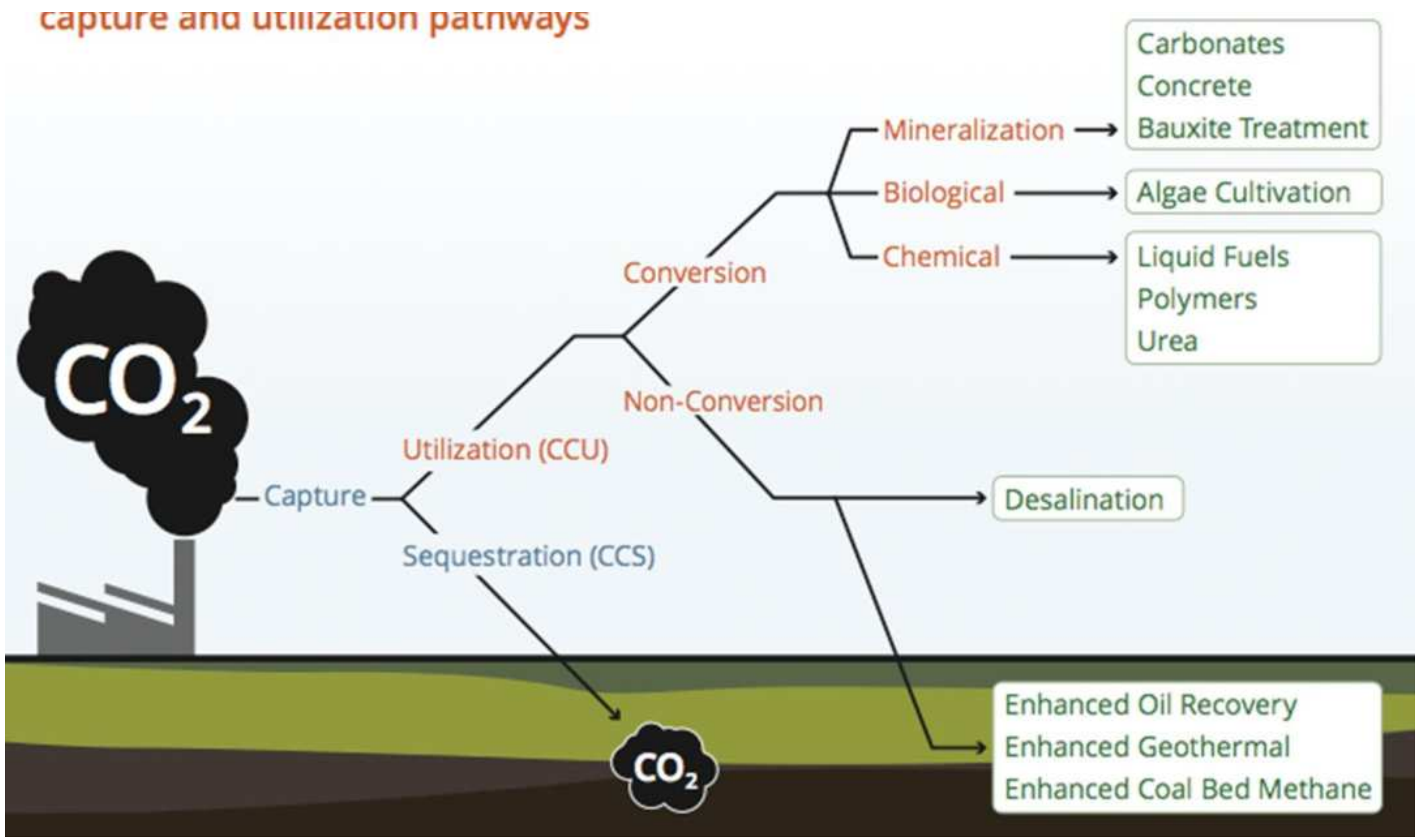


Mineralization technology is based on reacting CO_2 with calcium (Ca) or magnesium (Mg) oxide to form a solid carbonate mineral structure. These materials can be found either in natural form (also seawater) or in waste streams (e.g. wastewater brine). The reaction is exothermic (releases energy as heat)

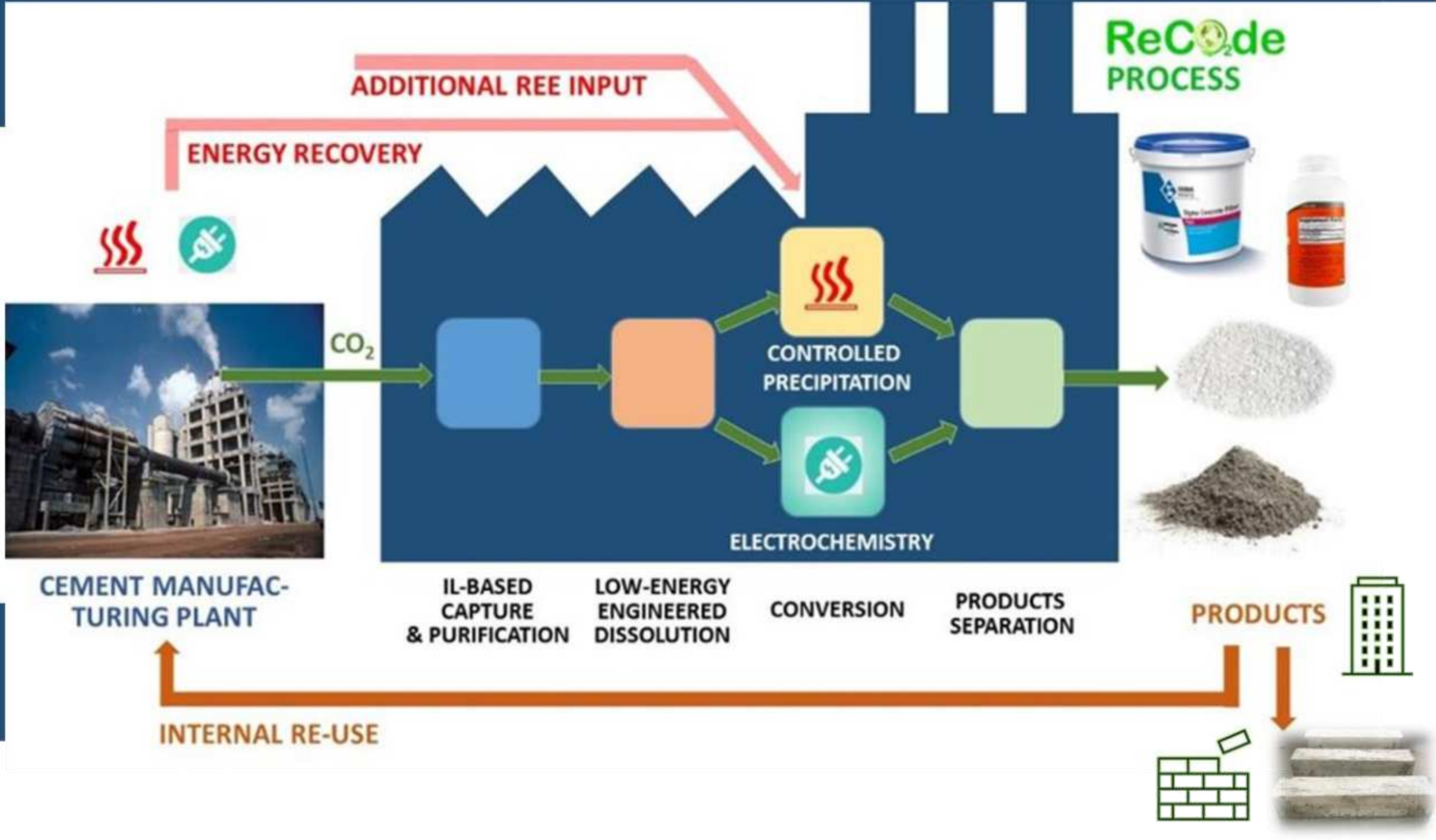
The RECODE project

Concept

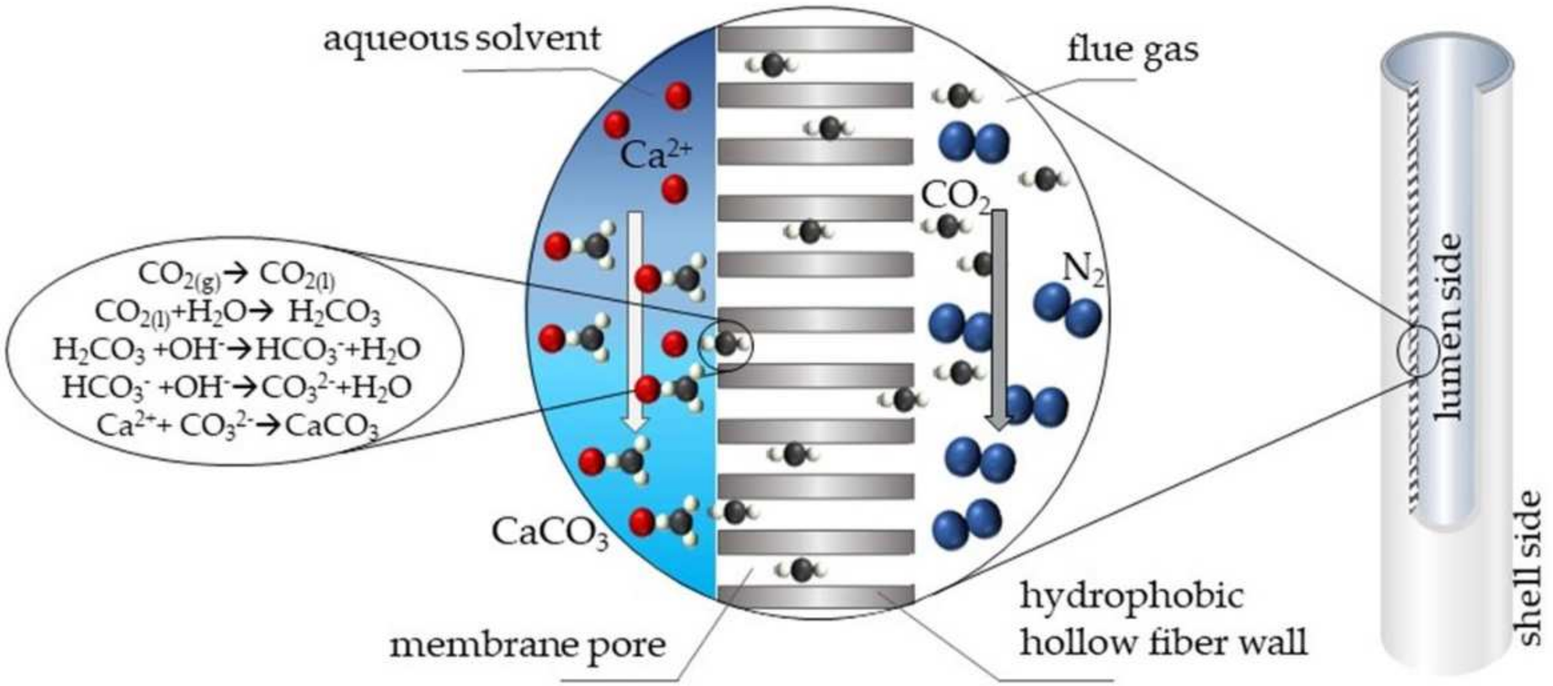
Recycling carbon dioxide in the cement industry to produce added-value chemicals & materials to enhance cement quality: a step towards a CO_2 circular economy

August 2017 - January 2022

A NEW IMPACTFULL TECHNOLOGY



The Innovative MGA Technology



Hollow fibre Membrane Precipitator Reactor concept
Simultaneous carbon capture and mineralization process
Highly-efficient, compact and modular design

The Innovative MGA Technology

TITAN TRL 6 pilot plant in the Kamari plant

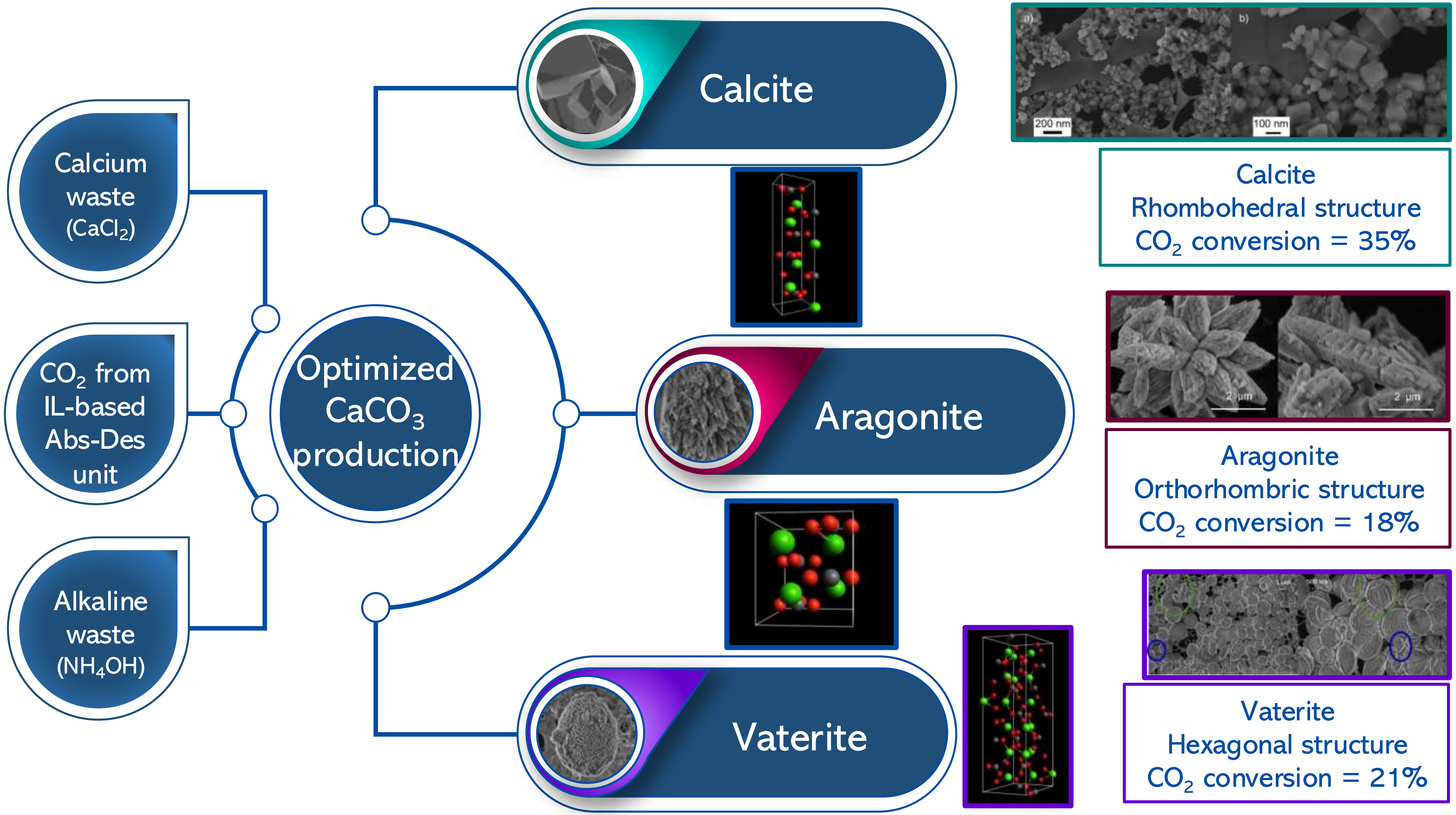
met. Politecnico di Torino CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

At 100 % of capacity:
3 kg/h $CaCO_3$

CO_2 conversion >20%.

Valuable by-product:
0.01kg/h of NH_4Cl

The Innovative MGA Technology



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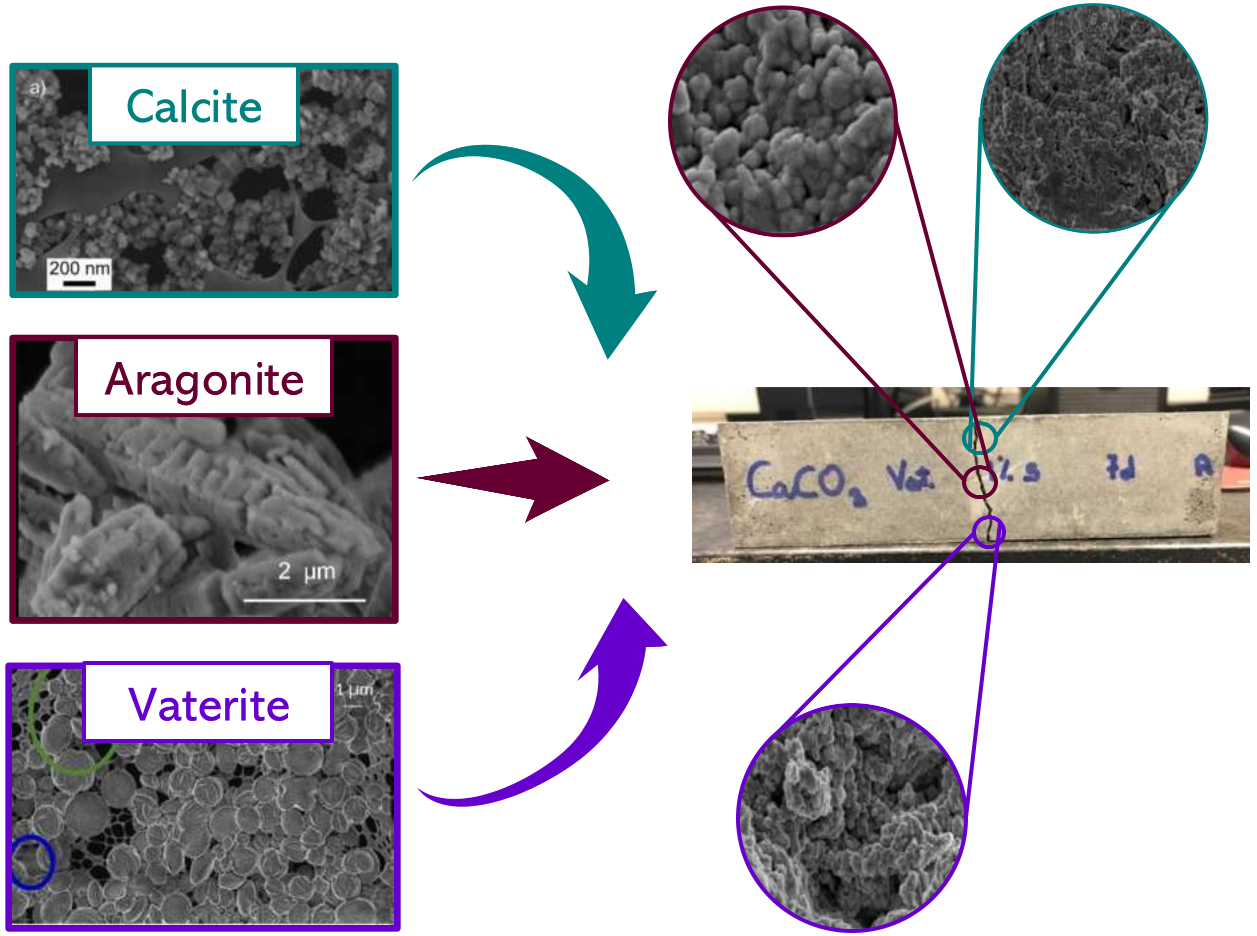
Impact Analysis

Evaluation of nano$CaCO_3$ product quality as cement filler



Substitution of clinker with 1-2% nano-$CaCO_3$ lead to up to 5 % improvement of **mechanical properties.**

Acknowledgements

RECODE *(Recycling carbon dioxide in the cement industry to produce added-value additives: a step towards a CO_2 circular economy)*

MemCCSea (*Innovative Membrane systems for CO_2 Capture and Storage at sea)*

CERESiS (*ContaminatEd land Remediation through Energy crops for Soil improvement to liquid fuel Strategies)*

PUREHy (*Development of biogas reformer with autonomous membrane systems for production and recovery of high quality hydrogen purity)*

DIGIKILN *(Recycling carbon dioxide in the cement industry to produce added-value additives: a step towards a CO_2 circular economy)*

En3DSyst (*Development of Advanced 3D Printed Membrane Systems for Power Generation Units)*

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