Position paper

October 2022

Carbon sinks

What role should research play in accelerating their development in France?

In order to remove CO_2 from the atmosphere, carbon sinks are a solution that is currently being considered as a unavoidable. Increasing but also preserving carbon sinks and, in some cases, restoring them, are priority issues. Based on a study by a group of experts from the ANCRE alliance, six major categories of carbon sinks have been identified for the French context: three categories of natural CO_2 capture solutions in more or less anthropised environments, and three categories of solutions integrating technological developments. The state of play, challenges, barriers and research recommendations for each of the solutions were highlighted in 7 worksheets.

Worksheet 1.
Carbon storage in biomass and agricultural and forest soils

Worksheet 2.
Carbon storage in biomass and soils in urban and anthropised environments

Worksheet 3.
Carbon storage in aquatic environments and from rock weathering

Worksheet 4.
Technological solutions for capturing atmospheric CO_2 for geological storage

Worksheet 5.
Storage of CO_2 in materials via mineralisation

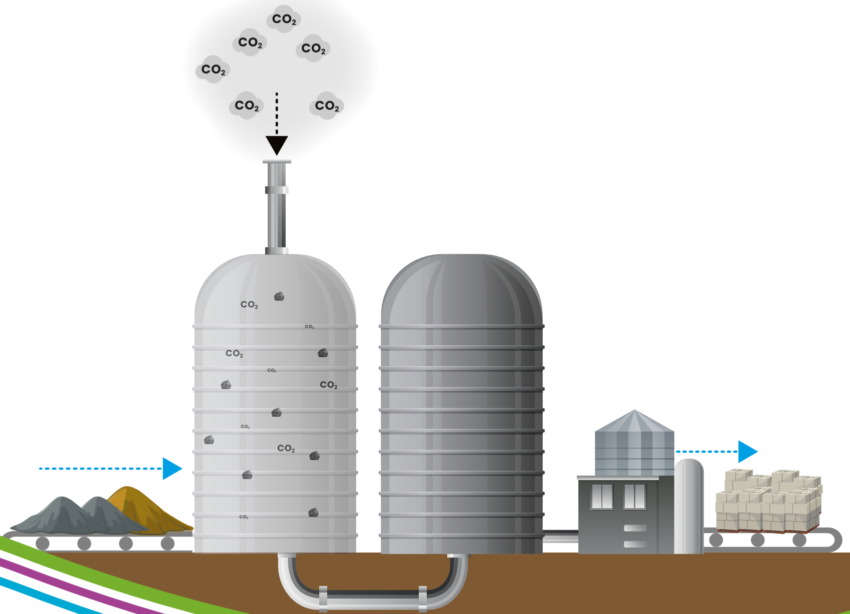
Worksheet 5bis.
Biogenic CO_2 capture and storage in bio-based materials

Worksheet 6.
Technological solutions for recycled carbon capture, utilisation, and long-term storage

The full report and each of worksheets are available on:
https://www.allianceenergie.fr/etudes-et-rapports/

ANCRE
Alliance Nationale de Coordination de la Recherche pour l'Énergie

Storage of CO_2 in materials via mineralisation



State of play

Mineralisation is a way of storing CO_2 in materials. It consists in accelerating the natural carbonation process known for its role in climate regulation using CO_2 from bioenergy, atmospheric capture or industrial gases. The cations (Ca, Fe, Mg) in the materials combine with CO_2 in the presence of water to form stable carbonates. Mineralisation occurs in ex-situ reactors which allow for fast kinetics and high yield. This CO_2 utilisation pathway can produce useful added-value materials from natural minerals, mine tailings or waste. This field is currently led by the USA, China, Canada, South Korea, Australia and the UK. It is also rapidly expanding with companies such as Carbon8, Carboncure, Solidia Technologies or MCi. A panoramic analysis reveals a high maturity of mineralisation for Calcium-rich feedstocks, in accord with the building materials sector.

				Calcium Feedtocks			Magenisum feedstocks	
				Ores (e.g. wollastonite)	Wastes (e.g. phosphogypse, BOF slag, deconstruction wastes)		Serpentinized ores (e.g. lizardite)	Not Serpentinized ores and wastes(e.g. olivine, nickel slags)
Solution	**Target**	**Products**	**Carbon impact**	Intermediate products : $Ca^{2}+$, $Ca(OH)_2$			Intermediate products : $Mg^{2}+$, $Mg(OH)_2$	
EX-SITU	Low carbon building materials	aggregates	Carbon sink	High maturity	High maturity	Significant R&D		Significant R&D
		Supplementary cementitious materials	Carbon sink	High maturity	High maturity	Significant R&D		Significant R&D
		Concrete blocks	Carbon sink	High maturity	High maturity	High maturity		
		Ready-mix concrete	Carbon sink	High maturity	High maturity	High maturity		
		Precipitated Ca/Mg carbonate	Carbon sink	High maturity	High maturity	Significant R&D	High maturity	
		Hydraulic binders (cement)	Avoided C		High maturity	Significant R&D		Significant R&D
	Other	Co-recovery of metals	Carbon sink		High maturity	High maturity		High maturity
		Co-production de H_2	Carbon sink	Significant R&D	Significant R&D	Significant R&D	Significant R&D	Significant R&D
IN-SITU	Storage		Carbon sink					Significant R&D

High maturity / commercial developments — Significant research and development — Largely unexplored

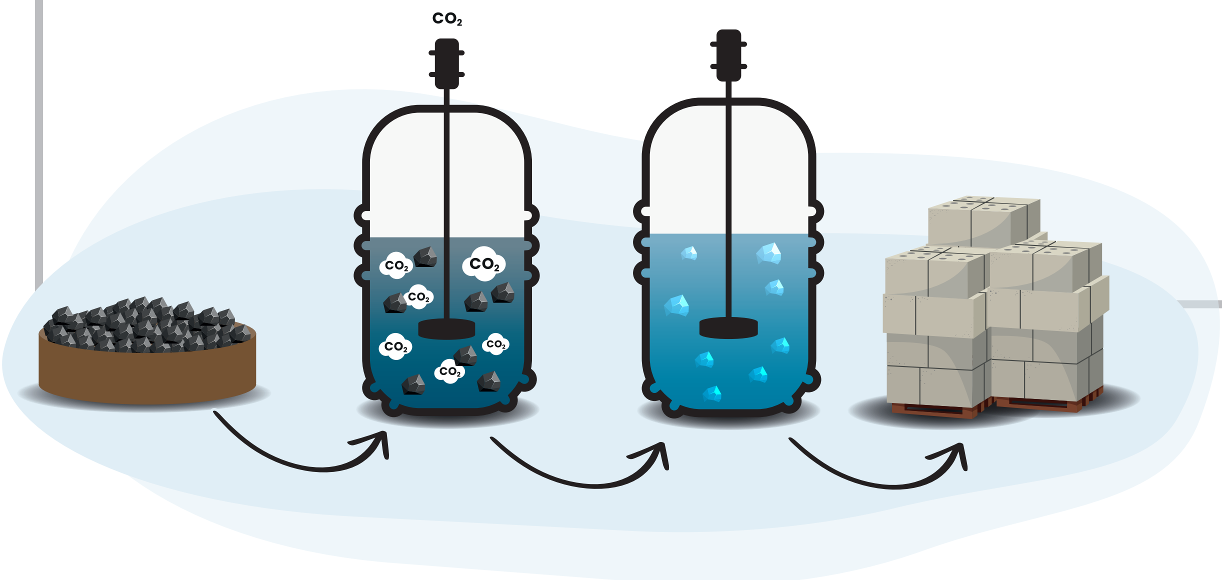
TotalEnergies, LafargeHolcim, Vicat, Air Liquide, Arcelor Mittal, Imerys, EDF, Eramet, Solvay and Veolia are active French companies in this area. The research side is led by CNRS, CEA, BRGM, CSTB, University Gustave Eiffel, University of Toulouse (LGC), University of Lyon (ICBMS), University of Paris and Université de Lorraine. The development of mineralisation in France is mainly at the R&D level for the production of valuable materials from industrial waste, with projects such as CARBOVAL , FASTCARB , VITAMINE and VALORCO . The coupling between mineralisation and metal extraction (MeCaWaRe Company), the production of H2 or the spreading of finely ground olivine for the capture of atmospheric CO_2 are among the most recent avenues of research and development.

1/ CARBOVAL (Mineralisation of waste from the mining industry) led by the University of Toulouse
2/ FASTCARB (Mineralisation of recycled concrete) led by the UGE and 22 partners
3/ VITAMINE (Mineralisation of CVE waste) supported by EDF
4/ VALORCO (Valorisation of CO_2 in the steel industry) supported by ArcelorMittal

Challenges

Achieving carbon neutrality in 2050 requires the development and deployment of CO_2 mineralisation technological solutions adapted to the French context, at the confluence of carbonatable material feedstocks, CO_2 emitters and markets. CO_2 sourcing is one critical issue for the development of mineralisation. It raises questions in terms of quantity, quality, availability, and economic value, during and after the transition period leading to the fully decarbonised energy mix foreseen by the French National Low Carbon Strategy (SNBC). CO_2 mineralisation using industrial by-products mainly concerns deconstruction waste (concrete, gypsum), ash and combustion products from coal or oil, incineration products (bottom and fly ash), mine tailings, and slags from metal manufacturing industries. It is estimated that the mineralisation of the approximately 2 billion tonnes of alkaline residues produced annually worldwide could (directly or through avoidance) reduce anthropogenic CO_2 emissions by 12.5% (Pan, SY et al. 2020). On the basis of 2019, it is estimated that the French deposit of carbonatable wastes could have made it possible to store approximately 6 Mt of CO_2. The carbonatable feedstock is likely to change over time. Despite the anticipated disappearance of certain wastes by 2050, such as ash and slag heap residues, new manufacturing processes that integrate CO_2 mineralisation could increase the carbonatable materials feedstock beyond 20 Mt of storable CO_2. This estimate is strongly associated with the construction sector, which has the capacity to turn cements/concretes into very large carbon sinks for CO_2 storage. The question of the availability of biogenic CO_2, i.e. not derived from fossil energy sources, is a point of vigilance.

5/ Expert estimates based on available carbonatable wastes (compilation of waste fluxes from various pathways in France, including French overseas territories).



Barriers

The development and deployment of CO_2 mineralisation processes in France (6 to 20 Mt of CO_2 equivalent) is based on access to and synergy between:

SUPPLY OF NON FOSSIL CO_2
constant over time, near carbonatable material feedstocks, with a high CO_2 content without penalising elements,

CARBONATABLE MATERIALS' FEEDSTOCKS
in sufficient and consistent quantity near CO_2 sources,

TARGET MARKETS FOR CARBONATED PRODUCTS
(e.g. building materials, precipitated calcium carbonate, flame retardants, mineral fillers, 3D printing).

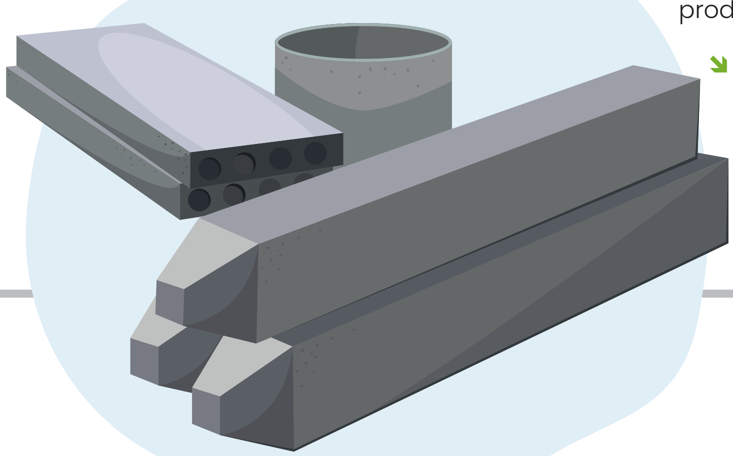
French actors in the development of CO_2 mineralisation technologies are few, and there is no industrial operator or industrial scale pilot or demonstrator in France yet. Due to the local nature of the feedstocks (CO_2, wastes) and associated markets, CO_2 mineralisation appears to be adapted to the scale of SMEs. It is imperative that mineralisation projects be evaluated using a systemic analysis of their economic and environmental benefits for the territory where their deployment is planned. The valorisation of mineralisation co-products (e.g. H2, metals) is an additional lever to fast-track the economic development of CO_2 mineralisation.

Actions

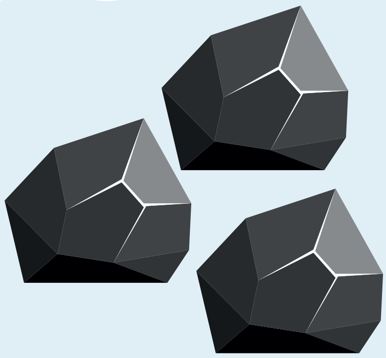
Priority actions to support the development of CO_2 mineralisation processes in France concern all TRL levels, from research to industrial deployment.

Research recommendations

- Enrich thermodynamic and kinetic databases for quantification of the mineralisation potential of carbonatable feedstocks.
- Increase mineralisation kinetics under the most favourable implementation conditions possible (e.g. development of innovative catalytic or biological pathways).
- Develop innovative technologies aimed at the full use of carbonatable feedstocks.
- Explore all possible ways of recovering mineralisation products, for all types of wastes and CO_2 sources (e.g. construction materials, scavenging of toxic metals present in wastes, functionalisation of products, etc.).
- Develop multi-product mineralisation processes (e.g. coupling with production of metal, H2, etc.).
- Integrate CO_2 mineralisation into the eco-design of commercial products.
- Explore the coupling between CO_2 mineralisation and DACC, since DACC is the only capture process capable of producing a controlled CO_2 stream that precisely matches the CO_2 consumption capacity of a given CO_2 utilisation process.



Implementing recommendations



- Mapping CO_2 and carbonatable waste feedstocks on environmental and economic performance criteria specific to the development of mineralisation pathways (development of a GIS dedicated to CO_2 mineralisation).
- Develop methods for quantifying the environmental and economic impact of mineralisation technologies and processes on a territorial scale.
- Develop technologies for integrating mineralisation into industrial production systems.
- Investigate synergies between mineralisation and geological storage of CO_2, where CO_2 and mineralisation mass flows do not match.