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 $_2$ 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

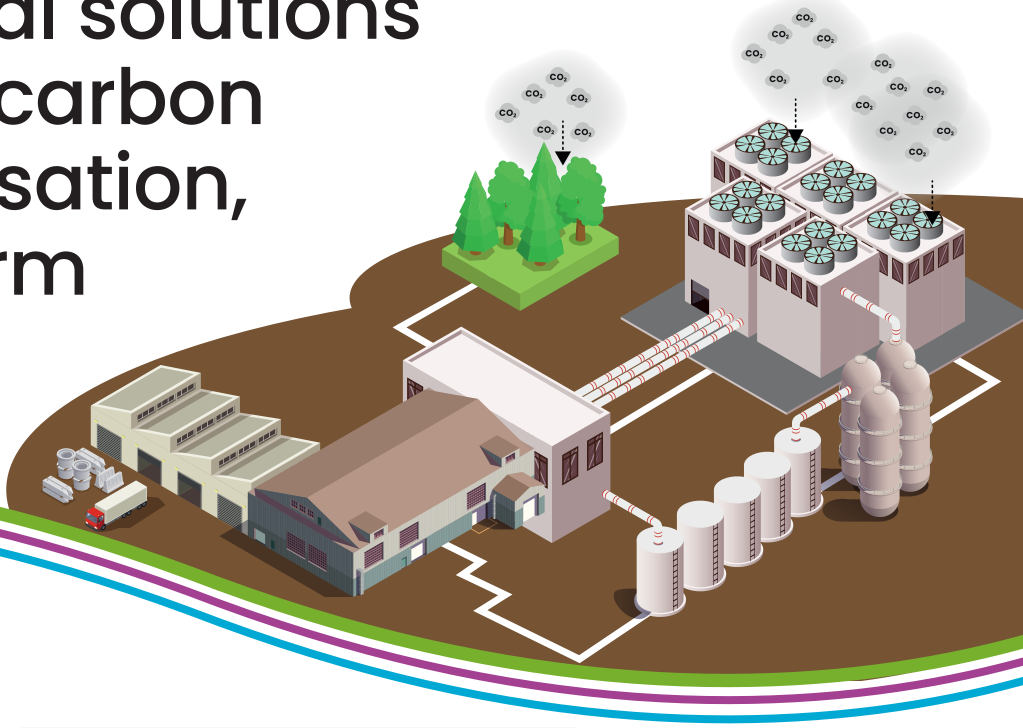
Worksheet 5bis.
Biogenic CO2 capture and storage in bio-based materials

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

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

Worksheet 6

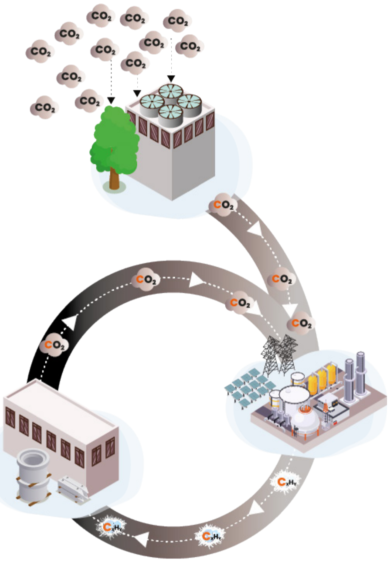
Technological solutions for recycled carbon capture, utilisation, and long-term storage



State of play

From the perspective of a carbon sink analysis, the capture and recycling of CO2 generated by an anthropogenic activity can be classified into different categories, depending on the use:

- mineralisation use. The carbon in CO_2 becomes a constituent of a mineral material and can be stored for the long term. This becomes a carbon sink if CO_2 comes from atmosphere (see worksheet 5)
- successive reuses of atmospheric CO_2, directly or after capture in a bioenergy/biorefinery unit, or direct conversion of biomass into bio-based materials (whose non-reuse issues are dealt with in worksheets 4 and 5bis)
- closed looping of biogenic or atmospheric industrial concentrated CO_2 in one or more industrial plants.



Towards the development of CO2 recovery and reuse for sustainable sequestration

Closed-loop CO_2 projects are called CCU (Carbon Capture and Utilisation). They currently mobilise concentrated industrial or fossil CO_2 with the aim of achieving carbon neutrality. Then, carbon storage is not what motivates the synthesis of the molecules. They are intended to provide industrial and energy services without depending on primary extraction of fossil resources. Therefore, they allow for the reduction of CO_2 emissions, more than a possible sink. However, some industrial processes and associated products could be capable of producing negative emissions by introducing CO_2 captured from the atmosphere into a closed industrial loop. France has already launched research projects and demonstrators in the fields of fuel production or high added value molecules.

These include JUPITER 1000[1], Methycentre[2], CIMENTALGUE[3], VASCO2[3], HYNOVI[4], REUZE[4], HYNOVERA[4] and HyCaBioMe[5]. Numerous other projects are currently emerging within the framework of programmes supported by ADEME (ZIBAC) in the Dunkirk, Fos-sur-Mer and Le Havre areas, as well as via the Innovation Fund[6] and the IPCEI[7]. French maritime transport is also communicating on a circular carbon economy strategy that effectively considers the use of CO_2 in a closed loop. In this concept, cargo ships could embark capturing devices, in order to capture and store CO_2 emitted by their own stacks, from fuel combustion. The CO_2 resulting from the combustion of these ships' fuels would thus be entirely captured and stored in compressed or liquefied form in the ship which would unload it in the port, to be sent, for example, to a synthetic fuel plant (which could supply these same ships). Through this process, a significant volume of carbon would be sequestered in a closed loop and could generate negative emissions, if CO_2 of biogenic or atmospheric origin is used. The sufficiently long duration (several decades) of this closed cycle remains the indispensable condition for granting the status of sink to these sectors.

1/ JUPITER 1000, a Power to Gas demonstrator with CO2 capture from the chemical industry, supported by GRTgaz

2/ Methycentre, a biogenic CO2 methanation project from biogas, supported by Storengy

3/ CIMENTALGUE and VASCO2, projects for the production of algae from industrial CO2, led respectively by VICAT and the Port of Marseille

4/ HYNOVI, REUZE and HYNOVERA, plants for the production of synthetic fuels from renewable hydrogen and industrial CO2

5/ HyCaBioMe, H2 and CO2 conversion project by biological methanation

6/ Innovation Fund: European funding programme - https://ec. europa. eu/clima/eu-action/funding-climate-action/innovation-fund_en

7/ "Important Projects of Common European Interest" (IPCEI): European mechanism for the promotion of innovation - https://competition-policy. ec. eu- ropa.eu/state-aid/legislation/modernisation/ipcei_en.

Challenges

The characterisation of negative emissions/carbon sinks cannot be dissociated from the period length during which this carbon is removed from the atmosphere, in order to get climate benefits. It is therefore necessary to establish consistency between the sustainability of a carbon sink and the climate mechanisms impacted by the life span of CO_2 in the atmosphere. This point remains difficult to settle because the literature does not show a consensus on a precise duration. A scale of around 100 years has been mentioned, a duration that would allow, a priori, a transition of humanity to carbon neutrality. Should we assume that a sequestration period equivalent to the residence time of a CO_2 molecule in the atmosphere after its emission (order thousands of years) is necessary, in order to affirm that a CO_2 sequestration process in a product can be qualified as a carbon sink operation?

As a matter of fact, the rating of a process or a product containing carbon must take into account the temporal issue and the conditions to be maintained over time to ensure the effectiveness of a carbon sink on the studied scale. If a product has a short life but can be recycled, these conditions are for example:

- the recycling rate is very efficient (close to 100%)
- this recycling is carried out and guaranteed for the minimum duration, estimated necessary to characterise the CO_2 use as a carbon sink.

If 100 years is taken as a reference for the duration of CO_2 sequestration in CCU products, then chemicals, fuels and polymers cannot represent favourable vectors for the generation of carbon sinks except in the case of very efficient and long-lasting recycling.

Hence, this raises questions about the performances of the recycling processes associated with the issues of dispersion or collection of the products. There are few, if any, examples of products currently recycled at rates close to 100% on industrial scales. The steel sector is probably the one that achieves the best process recycling performances but it is still dependent on upstream collection strategies.

Similarly, the condition of guaranteeing the recycling of a product for a period of 100 years is a challenge. It seems difficult to bet that nothing in the next century will break this virtuous process of recycling (economic interest, competing products, major conflict, recovery in a form of partial valorisation neglecting the value of carbon).

The challenge is therefore to:

- identify processes and/or products from CO_2 conversion/upgrading that can generate carbon sinks over sufficient time periods (at least 100 years).
- develop efficient recycling/re-utilisation systems that ensure sustainable use at an affordable quality of service.

Barriers

Apart from mineralisation, no CCU processes currently exists, that allow for permanent CO_2 storage and thus negative emissions. These processes do not constitute carbon sinks, if based on the proposed requirements and the expected service. In addition to the barriers associated with the capture and storage steps mentioned in worksheets 4 and 5, some specific technical barriers can be looked at, such as:

TECHNICO-ECONOMIC BARRIERS
associated with the issues of collection, sorting and recycling (energy consumption, yield), reuse (cleaning, maintenance of product performance), which are also found in the issue of bio-based materials (worksheet 5bis),

INTEGRATION OF CAPTURE DEVICES
and synthesis, in the existing industrial network

MASSIVE ELECTRICITY PRODUCTION
needed for CCU processes (CO_2 capture and conversion using decarbonised hydrogen),

IDENTIFICATION OF INNOVATIVE CAPTURE PROCESSES
of CO_2 in the exhaust, such as that emitted by vehicles with thermal engines, similar to the strategy mentioned by the shipping industry.

Actions

Before mentioning possible actions, it is important to make some recommendations on how to consider the CCU. These recommendations are part of the accompanying actions.

Implementing recommendations

- Do not systematically link the notion of carbon sinks/negative emissions to CCU processes with storage solution.
- CCU processes to polymer materials, chemical molecules and fuels are mostly dedicated to CO_2 emission reduction or avoidance, based on carbon recycling.

When CO_2 is recycled and valorised in short lifespan products (fuel, chemicals, etc.), the production processes must be combined with other processes to recover all or part of the CO_2 in order to be considered as sink (e.g. BEECS system described in worksheet 4).

In terms of research actions, we can distinguish between avoidance and sink solutions. Therefore, it is important to:

Research recommendations

- Evaluate systems by using multi-criteria analyses, including techno-economic assessment and carbon footprint aspects using 'well to wheel' approaches based on LCA which requires methods developments. The assessments will aim to establish, through balances, the service provided, the gain in terms of emissions and the constraints of these systems (in particular linked to the necessary massive production of decarbonised energy).
- Develop efficient CO_2 capture processes, in order to achieve high recycling rates. While these systems exist for fixed and centralised industrial processes, they must be developed and require specific developments of CO_2 transport and capture pathway for decentralised (residential) or mobile systems.
- Develop efficient CO_2 conversion systems at different scales to produce fuels or materials.
- Develop the interconnection of CO_2 conversion processes with the location of capture processes. This mean developing the transport of CO_2 as a feedstock and thus developing infrastructure (pipes, networks, etc.), for example between the CO_2 unloading area from a boat and the synthetic fuel production infrastructure.