Co-funded by the European Union

Case study on the results, challenges and learnings from the clustering of biogas plants in France

Lessons from BioCO2 Nancy project

CETP CO2RR

December 2024

Key messages:

BioCO2 project partners have demonstrated the technical maturity of BECCS projects based on the capture, liquefaction and sequestration of biogenic CO2 from decentralised biomethane production units using sustainable agricultural waste as a feedstock.

However, the project is facing challenges on the commercial front due its high costs and to the weakness of demand for high-integrity carbon removal credits on the voluntary carbon market and the absence of national support mechanisms.

For projects such as BioCO2 Nancy, national or European public support – for example, in the form of capital or operational expenditure incentives per tonne of CO_2 – would help jumpstart the BECCS approach based on decentralised biomethane plants in France and Europe. This support is critical to compensate for the structural deficiencies of such projects today, namely, high transport costs.

High transport costs result mostly from the modular combination of truck and rail to transport the ISOtainers to the storage sites which is inherently expensive. They will be mitigated over time with optimised, modular liquefaction units, increased CO_2 volumes transported from France to the North Sea, economies of scale realised by using direct, full trains and leveraging larger transport modes such as barges and ships, and, eventually, transport by pipeline.

Development of local onshore CO_2 sequestration infrastructure is technically feasible and would further decrease costs for the corresponding carbon removal credits, thus enabling a faster scale-up.

About the project

This work was funded by CETPartnership, the Clean Energy Transition Partnership under the 2022 CETPartnership joint call for research proposals, co-funded by the European Commission (GA N°101069750) and with the funding organisations detailed here.

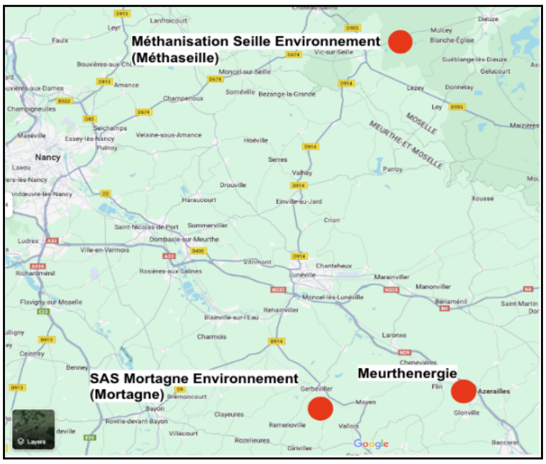
The project is supported by the French Environment and Energy Management Agency ADEME and the Swiss Federal Office of Energy SFOE.

Within this framework, the Carbon Rhine Route project is developing pathways for inland European emitters to access carbon capture and storage, supporting the scale-up of carbon dioxide removal (CDR). Consortium partners include Carbon Impact, Airfix, Chemoil Logistics and Northern Lights.

BioCO2 Nancy project context:

Aerial view of Méthanisation Seille Environnement

Carbon Impact was approached at the end of 2022 by a group of three biomethane plant owners who were investigating the potential of biogenic carbon dioxide (CO2) emitted by their production units near Nancy in France.



- Site 1: Mortagne
- Site 2: Meurthénergie
- Site 3: Méthanisation Seille Environnement

Carbon Impact completed a prefeasibility study in the first half of 2023 that was awarded to Naldeo, a process engineering firm and co-financed by BPI France. The study led to the BioCO2 Nancy bioenergy with carbon capture and storage (BECCS) project.

BioCO2 Nancy project description:

BioCO2 Nancy aims at capturing, purifying and liquefying ~12,000 tonnes of CO_2 from the off-gas of three biogas purification units, in order to condition it for road transport in liquid phase. Liquid CO_2 transport is required to transfer the CO_2 from its point of emission to its sequestration location in Northern Europe, in the absence of an alternative scheme (e.g. dense phase transport in CO_2 pipelines).

The biomass feedstock of the three biomethane plants is composed of agricultural waste, with the quantities described below (in line with the EU's Renewable Energy Directive (RED II)):

Type of input (tonnes per year)	Mortagne	Meurthénergie	Méthaseille
Manure/ slurry	10,000	28 600	35,000
Maize	1,600	700	2,750
Grass	350	300	
Intermediate crop for energy recovery	1,100	3,700	17,250
Cereal waste	500	2,400	
Waste from the agri-food industry (potatoes)	300		
Waste from the food industry (sugar)	400	300	
Waste from the food industry (fruit)	300		
Total (tonnes per year)	**14,550**	**36,000**	**55,000**

Currently the main output of the three biogas plants is biomethane produced from biogas using a gas separation process. More specifically, the raw biogas resulting from agricultural residues' anaerobic digestion (including 50–70% of methane and the remainder mainly CO2) is compressed and processed through membranes and an activated carbon filter resulting in:

- pure biomethane which is injected into the French gas network;
- a gas mix (the off-gas) including mostly CO2, ~1–2% of methane (so called methane slip) as well as some water vapour, oxygen, nitrogen and traces of impurities.

The BioCO2 Nancy project consists of installing on each site an off-gas purification and liquefaction unit. Purification of CO_2 from a gas mix, as well as the cryogenic liquefaction of CO2, are mature processes widely used in chemical and other process industries. The processes have also recently been applied to biogas and biomethane production facilities in Europe. CO_2 purification and liquefaction systems from biogas origin are commercially available for the food & beverage and greenhouse industries. The BioCO2 Nancy project would be one of the first to implement the BECCS concept with geological storage at an industrial scale.

CO2 purification and liquefaction units involve the following main steps:

1. Compression: The flue gas enters an intermediate storage tank, which separates the two systems and protects them from pressure fluctuations. An operating pressure of 18 bar is achieved by means of a multi-stage compressor. The heated gas is cooled and residues, such as aerosols from oil residues, accumulate as condensate and are separated.

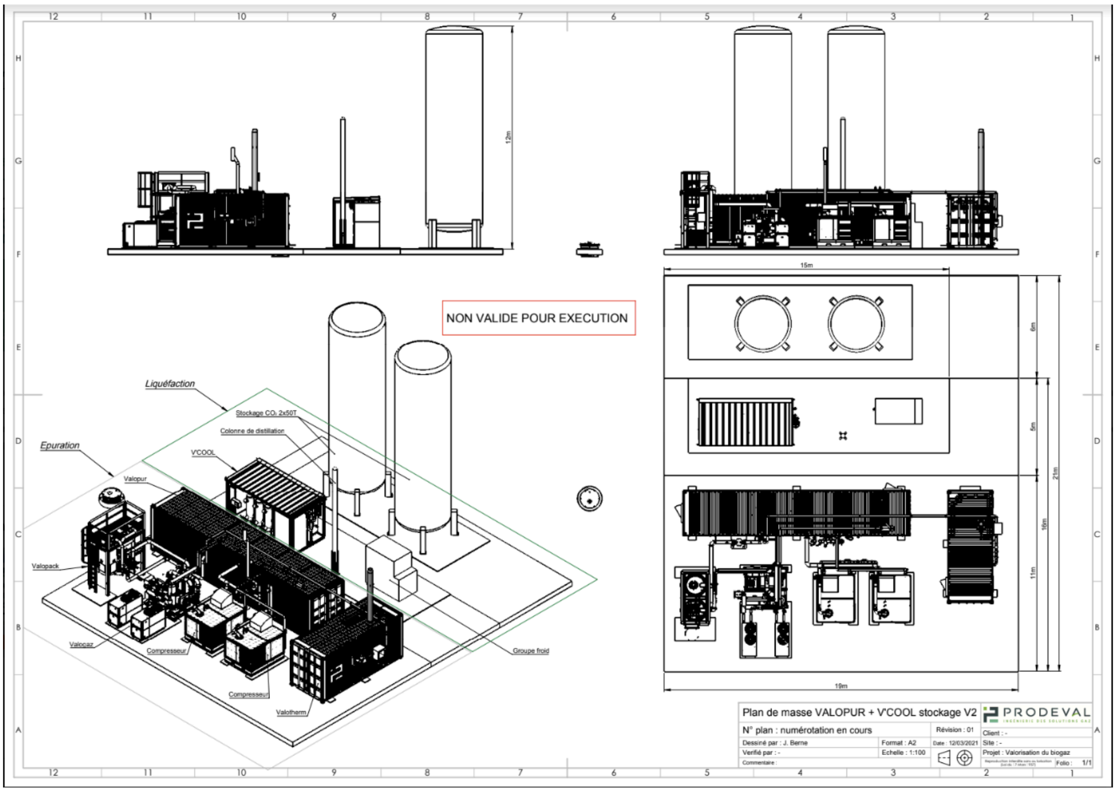
2. Gas purification and drying: An activated carbon filter removes odours and flavours. In addition, the gas is dried using an appropriate dehumidification process.

3. CO2 liquefaction: A cooling circuit cools the gas to below the condensation point of -24 °C. This liquefies the CO2, while other substances remain in gaseous form and

are separated out. Any remaining impurities that have dissolved in the liquid CO_2 are removed in a distillation column. The purified and liquefied CO_2 is temporarily stored in a vacuum-insulated tank at -24 °C and 18 bar.

4. Methane slip recirculation: Most of the methane in the flue gas remains in the gas phase during liquefaction. In the distillation process, the methane dissolved in the CO_2 is also recovered. This means that the entire methane slip can be removed from the flue gas flow and returned to the biogas plant.

A dozen equipment manufacturers were identified for the construction and integration of the liquefaction and local storage equipment. Among them was Prodeval, a leading gas treatment company who are also the providers of the biogas separation units of the three biomethane plants and have established relationships with the three biomethane unit owners. Prodeval provided a technical proposal for the purification and liquefaction equipment, as illustrated in the following visual.



Groundplan for the CO_2 purification and liquefaction units

After liquefaction and purification, one option is to transport the liquid CO_2 in cryogenic containers (ISOtainers) via transport by truck (road) and train (rail) to the Northern Lights injection site in Oygarden, Norway, for permanent geological storage. The site (as shown in the following figure) is currently under construction and should be ready in 2024 for receiving and injecting the first CO_2 delivered by ship. Other CO_2 permanent sequestration sites will also be available for example in Denmark.

Aerial view of the Northern Lights site in Oygarden

Business model:

The project will derive its revenues from the sale of carbon dioxide removal (CDR) certificates on the voluntary market accounting for 10,000 tonnes per year (the net of life cycle emissions, described below).

The voluntary carbon market for long-term carbon removals is currently estimated at 5.2 million tonnes per year for a value of 2.1 billion euros in 2023 according to CDR.fyi. It is further expected to grow to 40–200 million tonnes per year by 2030 according to a study by the Boston Consulting Group. BECCS is considered as one the most promising and most mature CDR methods.

CO2RR consortium partners Airfix and Carbon Impact are currently actively commercialising the CDR certificates from BioCO2 Nancy with an objective of securing 2–3 buyer commitments in 2025.

The sales will be contracted via multi-year offtake agreements (of at least 5 years, but ideally 10 years or more). Offtake agreements from credit-worthy buyers will allow financing of the assets of the project (capital expenditure [CapEx] and working capital) using a mix of equity and debt.

The project is expected to follow the Verra Carbon Capture and Storage methodology, whose module for bioenergy facilities was released on March 1st 2024 for public consultation. The methodology will then be finalised and published in its final version before the end of 2024. Alternatively, Puro.Earth has an existing methodology under which the project would also be eligible.

The project partners have assessed the life-cycle emission losses along the value chain at around 10%. The main losses include emissions during CO_2 transport (mostly by land). To a lesser extent, some CO_2 emissions result from the liquefaction process, which consumes electrical energy (in the range of 250 kWh/tCO_2) sourced from the French power grid, as well as emissions for compression at the storage site.

Permitting:

The project partners have a clear roadmap to comply with the regulatory requirements across its full value chain, outlined below.

- The capture of CO_2 at the biomethane plants will require a construction permit delivered by the local authorities. Permits for such units are already delivered on a regular basis in France.

- The most recent version of the EU CCS Directive authorises the transport of CO_2 across borders between EU member states without the requirement for a bilateral agreement. However, in order to start transporting the CO2, the project will be required to provide appropriate documentation on the CO_2 (e.g. material security data sheet) and ensure its logistics providers have the necessary permits to transport CO2.

- As Norway is not an EU Member State, the country is not automatically subject to the full EU CCS Directive. However, they have demonstrated their commitment to enabling the storage of CO_2 from EU Member States through bilateral agreements. The Norwegian and French governments are in active discussions around collaboration on CCS which includes negotiation of a bilateral agreement to enable storage of CO_2 from France in Norway. An agreement was also signed between France and Denmark paving the way for sequestration in that country as well.

Financing plan (public version):

The main CapEx item is the purification and liquefaction equipment to be procured from a manufacturer.

In addition to CapEx, the project will require additional funding for working capital, mostly resulting from the 1-year lag between the start of CO_2 transport and sequestration, and the payment of certificates by carbon credit buyers. This lead time results from the requirement to implement the certification process and allow verification of the removals by third parties before actual issuance of the certificates and their subsequent payment.

Public support mechanisms are available at EU level via the Innovation Fund, but are competitive in nature. For now, no public mechanisms are available in France for this type of project.

Project status:

BioCO2 project partners are still in an active phase of project carbon credit commercialisation. The selling price of credits is in the range of 600 euros per tCO_2 (net of life cycle costs).

Project partners notably applied to different platforms – such as the CDR request for proposal (RFP) processes for Microsoft, Frontier and NextGen CDR Facility – and also directly approached corporate buyers.

So far, the market feedback is that the project is of high quality and integrity with regards to the voluntary carbon market criteria for negative emissions. This is because of the robustness of the CO_2 sequestration method and the sustainability of the biomass feedstock used (agricultural waste). However, the price per tonne is high compared to other BECCS projects in Europe on the market that manage to secure offtake contracts in price ranges approximating 200–300 euros per tCO_2.

This high price for BioCO2 Nancy results from the relatively high costs to transport the CO_2 from Nancy to North Europe in relatively small quantities (in the range of 300 euros per tCO_2) to be added to capture, liquefaction, sequestration and certification costs (accounting for more than 200 euros per tCO_2 in total, half of which accounting for liquefaction).

The BioCO2 Nancy project partners are convinced of the relevance of such BECCS projects, because of the potential to scale down costs across the value chain as the approach is duplicated to a larger number of biomethane units, as detailed below.

- Capture and liquefaction costs can be optimised by standardising the equipment and deploying modular units procured through long-term supply agreements with manufacturers, which can in turn benefit from lessons learned from the initial deployments to decrease costs and improve efficiency.

- Beyond capture and liquefaction, there is a clear roadmap for the transport costs to decrease over the lifetime of the project. This evolution is due to the increased CO_2 volumes that will be transported from France to the North Sea, as more emitters (biomethane plants but also other biogenic and fossil CO_2 emitters) equip their plants with carbon capture infrastructure.

- The current envisaged transport modality, combining truck and rail to transport the ISOtainers to the storage sites, requires quite a number of changes (from truck to rail, rail to rail as there is no direct train, rail to truck) which makes the transport service expensive. By increasing the transported quantities economies of scale will materialise for example by using direct, full trains and leveraging larger transport modes such as barges and ships.

- Eventually transport by pipeline will allow another level of cost reduction and project competitiveness for BioCO2 Nancy and other similar projects in the longer run.

- Finally another option would be to sequester the CO_2 onshore, closer to the biomethane facilities, thus decreasing both transport and sequestration costs significantly (discussed in the next section).

Potential of onshore sequestration:

BioCO2 project partners have also investigated the potential for onshore storage closer to the biomethane units. To this end a study was commissioned from Eosys, a French geoscience expert firm to investigate the potential of geologic CO_2 sequestration close to the biomethane plants.

The study's conclusion is that there is a wide range of geological possibilities for confining CO_2 in the vicinity of the 3 biomethane plants, either temporarily or permanently both in the Lorraine Basin but also in the nearby Plaine d'Alsace, which has the same stack of geological structures.

Local underground containment capacity should be more than sufficient to accommodate CO_2 emissions from existing biogas plants and their ramp-up, as well as emissions from other local emitters from other local industrial facilities. If and when developed, local sequestration capacities will be key to improve the cost structure of BECCS based on the capture and sequestration of biogenic CO_2 from biomethane plants.