

Feasibility study of a CCUS project in Dunkirk

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The storage and utilization of carbon dioxide (CO₂) is a crucial challenge in the fight against climate change and the transition to a sustainable economy. CO₂ is one of the main greenhouse gases, and its accumulation in the atmosphere, resulting from human activities such as combustion and industrial processes, contributes significantly to global warming.

In this context, this report presents the results of a feasibility study for the construction, within the Flanders Facility (EF), of a CO₂ utilization unit and a CO₂ liquefaction and export terminal by ship.

TotalEnergies' Flanders Facility is located in Dunkirk and carries out energy storage activities and training center operations. It is situated at the heart of an area hosting several CO₂-emitting industrial sites, including one of the largest industrial emitters in France. Some of these industrial players have launched decarbonization plans, one component of which involves CO₂ capture.

In parallel, NaTran (formerly GRTgaz) has carried out preliminary studies for the creation of a CO₂ collection network for industrial sites in the industrial and port area.

The proximity of the emitters and of NaTran's planned network, together with the availability of land and capacity on the EF jetty, led to the launch of this study.

The study boundaries start at the CO₂ supply to EF and end at the CO₂ loading arms on the jetty.

In order to rely on concrete assumptions, the study is based on the CO₂ volume to be processed and on the annual CO₂ production profile identified in March 2024. No seasonality is considered; CO₂ capture is therefore assumed to operate at a constant rate throughout the year. A ramp-up phase is planned over the first six years. The facilities, designed for a capacity of 3 Mtpa, have been engineered to ultimately accommodate a flow of up to 5 Mtpa, in view of the projects announced by industrial stakeholders in the area.

- For uses requiring CO₂ conversion:
 - Fuels:
 - Methane: Due to the low maturity of the technology, incompatibilities with the available CO₂ quality, high utility consumption (particularly H₂), and potential future regulations unfavorable to the market associated with the use of fossil CO₂, this technology was discarded.
 - Methanol: Although more mature than methane production technology, it presents the same disadvantages and was therefore discarded.
 - SAF (Sustainable Aviation Fuel): This technology has the same disadvantages as methanol production, except that the CO₂ quality is compatible in this case. Despite uncertainties regarding the future market for this product, this technology was selected.
 - Polycarbonates: The maturity of this technology and the potential of the associated market led to its selection.

The CO₂ flow rates to be processed were adapted to the electricity available on site or to standard designs from the literature if more restrictive. It was demonstrated that, with the current facilities, it was not possible to design a CO₂ utilization plant capable of processing the entire CO₂ flow.

This first selection phase led to the choice of three CO₂ utilization technologies for further evaluation, namely:

1. R744 production

✓ Advantages:

- Few production steps;
- Controlled production cost;
- Global market for low-GWP refrigerants is growing strongly (+45% expected by 2029).

✓ Disadvantages:

- Global market for low-GWP refrigerants = 1/3 of the flow in our design. The share of R744 in this market needs to be determined;
- Significant reduction of the design flow required → significant increase in production costs expected, plus conditioning costs to be added (excluded from the study).

2. SAF (Sustainable Aviation Fuel) production

✓ Advantages:

- Favorable regulations supporting the SAF market;
- Potential valorization of co-products (light naphthas) if little or no pre-treatment is required.

✓ Disadvantages:

- Production cost higher than the market price;
- Fossil CO₂: Expected regulatory changes by 2040 could reduce economic benefits (requirements for SAF share in aviation fuels, subsidies, etc.).

3. Polycarbonate production

✓ Advantages:

- Reduction of GHG emissions from the polymer.
- ✓ Disadvantages:
- Raw material requirements;
 - Technology not fully mastered: need for a technology provider.

At the end of the previous phase, the technology for producing SAF from green hydrogen (e-SAF) was selected for an optimization study. Indeed, market opportunities for R744 appeared limited, and it was found that polycarbonate production consumes only a small fraction of the available CO₂.

Design optimizations allowed a reduction in the process's electricity consumption. Since electrical power is a key sizing factor in this design, the design flow was increased to reach 14% of the available CO₂ flow. The study demonstrated that the installation is compatible with the available site area.

However, the levelized cost of production remains higher than the current market price, meaning profitability is not achieved and further optimization is required. Potential avenues for co-product valorization and additional technical optimizations were nonetheless identified.

With the need for a CO₂ outlet confirmed, the next phase of the study focused on sizing the CO₂ treatment, conditioning, and shipping facilities.

The liquefaction unit consists of a compression section followed by cooling and cryogenic distillation. Storage spheres are planned to hold the liquid CO₂ under Medium Pressure (MP) conditions (15 bar and -30°C). The liquid CO₂ is then transferred to the current EF jetty, whose docks have sufficient capacity to accommodate additional vessels. New loading arms, adapted to these conditions, will be installed to load CO₂ onto ships.



Figure 3: Aerial view of the planned layout of future equipment at the Flanders Facility

To account for the ramp-up during the first years, two configurations were studied for the liquefaction unit:

- A single train designed for 3 Mtpa.
- Two trains: one train designed for 1 Mtpa to start first, and a second train designed for 2 Mtpa to start later.

The EF site has sufficient available space to install these new units. A preliminary analysis of both new and pre-existing risks shows no incompatibilities.

CAPEX and OPEX for the solutions were studied. In the feasibility phase, OPEX (personnel, maintenance, etc.) are estimated by applying a percentage to CAPEX. The percentage depends on the type of unit and is determined by comparison with similar projects. Electricity represents a very significant portion of these OPEX.

The project schedule was analyzed, taking into account the various administrative constraints.

A number of uncertainties, risks, and opportunities have been identified. These are related to network routing, CO₂ specifications, ramp-up and seasonality, competing projects, as well as the development of CO₂ hub projects in other regions of France.

RÉSUMÉ

This report presents a feasibility study for a CO₂ utilization and export project aimed at reducing greenhouse gas emissions in the Dunkirk industrial and port area. The first part of the study focused on identifying and sizing the means of delivering CO₂ to the site. Pipeline transport was selected, and two options were evaluated: a dedicated pipeline or connection to a future shared network, to transport up to 3 Mtpa of CO₂, expandable to 5 Mtpa. Next, the study aimed to identify which existing CO₂ utilization technology would be suitable for the site. After a preliminary assessment of three possible solutions—R744 production, polycarbonate production, and sustainable fuels (SAF)—a SAF production unit was sized, associated with a CO₂ liquefaction and shipping terminal for maritime export.

The study did not identify a currently viable economic model for SAF production, but potential optimization pathways were highlighted. Conversely, the study confirms the technical feasibility of CO₂ transport, treatment, and liquefaction under pressure and temperature conditions suitable for export. The project incorporates a gradual ramp-up, optimized site layout, and leverages the technical choices made.

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