NORTH LINCOLNSHIRE GREEN ENERGY PARK

Planning Act 2008

Infrastructure Planning (Applications Prescribed Forms and Procedure) Regulations 2009

North Lincolnshire Green Energy Park

Annex 7 - Fichtner Report

PINS reference: EN010116

February 2025

Revision number: 0

FICHTNER
Consulting Engineers Limited

North Lincolnshire Green Energy Park Limited

NLGEP

CCS land area and potential to use CO_2 in eSAF and ePolymers

1 Introduction

North Lincolnshire Green Energy Park Limited (NLGEPL) is developing the North Lincolnshire Green Energy Park at Flixborough Industrial Estate. Central to the energy park is an energy recovery facility (ERF), proposed to process up to 760,000 tonnes per annum of RDF, producing up to 95 MW gross electrical power.

NLGEPL has engaged Fichtner Consulting Engineers Limited (Fichtner) to assesses the space requirements for capture of the full CO_2 volume produced by the ERF. In addition, NLGEPL has requested an overview of use cases for captured CO_2, focussing on production of eSAF and ePolymers.

2 Carbon capture

2.1 Requirements for carbon capture

Figure 1: CCS diagram

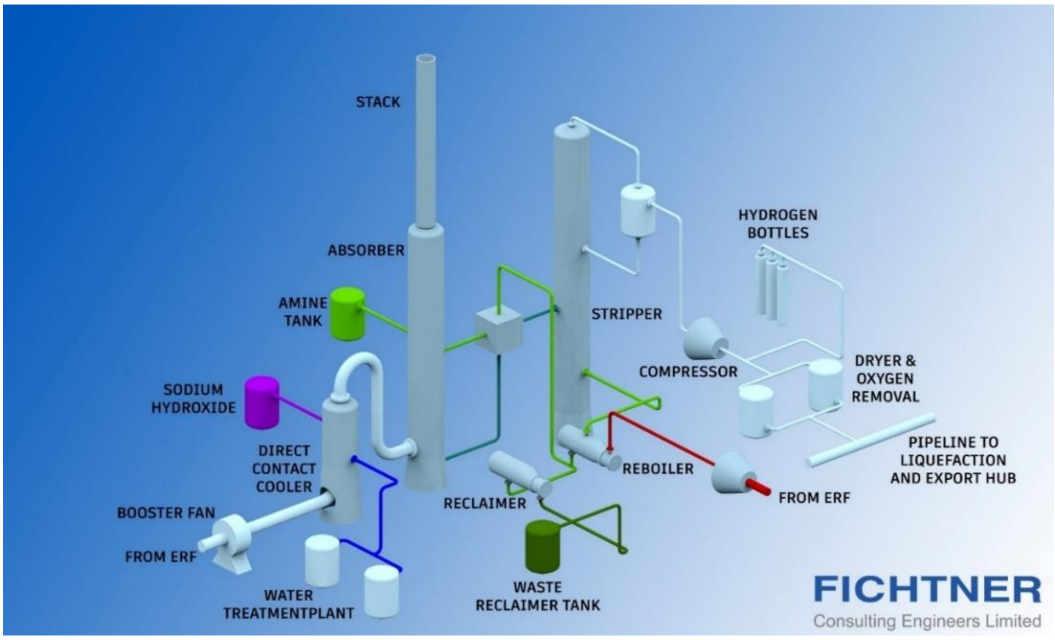


Figure 1 shows the key process stages in a carbon capture plant using amine based capture technology. In addition, to the equipment shown in Figure 1, additional equipment will be required to:

1. control the quality and composition of product CO_2 to the correct conditions; and
2. control the temperature and pressure for the requirements of the offtaker.

Depending on the offtaker, space may also be required for liquefaction and storage of carbon dioxide.

The space required for a carbon capture plant can vary, depending on several factors, including:

1. level of equipment sharing with the ERF:
    a. requirements for a separate, dedicated, turbine;
    b. adequate sizing of electrical equipment;
    c. adequacy of cooling systems for both the CCS and ERF plants;
2. offtaker requirements including:
    a. pressure;
    b. temperature; and
    c. state;
3. contractor layout and design strategy; and
4. environmental impacts, including noise, air quality and water quality.

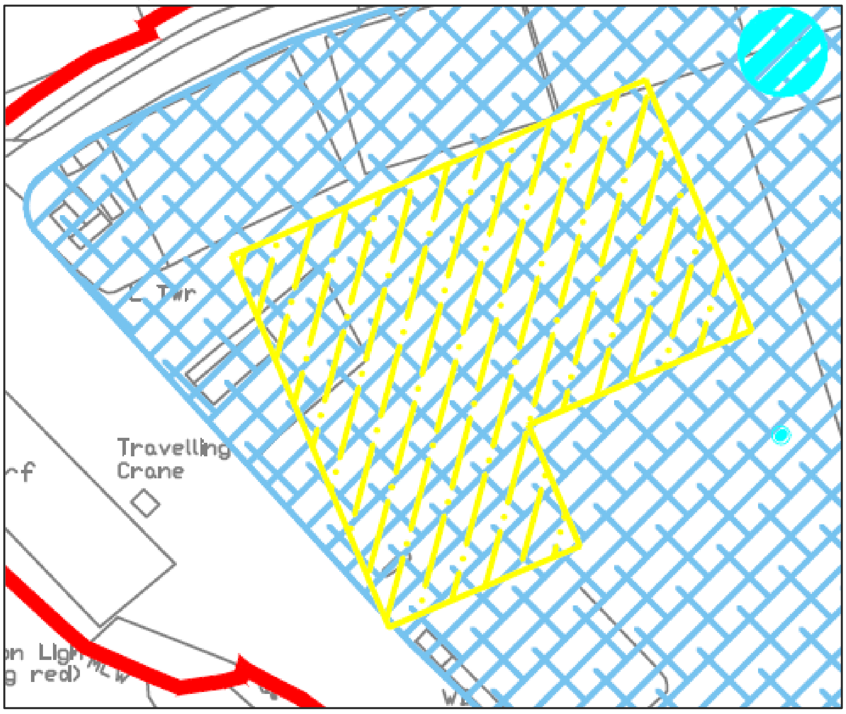
Of the carbon capture plants integrated with energy recovery facilities (ERFs) which have reached pre-FEED or FEED stage, and for which the development has been supported by Fichtner, plants required between 0.014 m^2/tCO_2/year and 0.041 m^2/tCO_2/year. Within this range, the average footprint was 0.028 m^2/tCO_2/year.

2.2 Space requirements

The NLGEP project has committed to capturing more than 50,000 tpa of CO_2 from the ERF flue gas in its development consent order (DCO) application. The captured CO_2 will be used in the carbonation of flue gas treatment residue (FGTr) for use in the production of aggregates for manufacturing of concrete blocks. Space has been allowed (yellow cross hatched area in Figure 2) for capture of this quantity of CO_2 within the DCO. As NLGEPL has since considered treatment of the full flue gas volume, which would require capture of approximately 650,000 tonnes of CO_2 (tCO_2), a larger area will be required.

Given that amine-based capture is recognised as the most established technology for capture of CO_2 from flue gas from ERFs, we have assessed the area that would be required for a full-scale capture plant based on this technology.

Figure 2: Works area for CCS



Assuming:

1. a capture rate of 650,000 tonnes annually;
2. an amine carbon capture process; and
3. a capture rate of 95%.

We estimate that the area required for full scale CCS at NLGEP will likely be in the range 9,000 to 26,000 m², with an average of 18,000 m² based on previous studies.

Calculating requirements for a plot plan based on a simple scaling method is inaccurate and does not consider nuances within process design. Any estimate will require design development to improve its accuracy.

NLGEPL will undertake detailed studies, including the following elements, to refine the design and estimated area, once the DCO consent has been granted:

1. thermodynamic or thermochemical modelling;
2. development of detailed process design;
3. approaching contractors and validating concept design estimates;
4. development of plot plans, including consideration of access and maintenance requirements;
5. constructability assessments; and
6. gas analysis on the flue gas to be produced by the facility, as the ERF has also not been constructed and no confirmed fuel source is available.

The details of how the NLGEP CCS plant will be built in practice will need to be worked out in more detail during the course of a pre-FEED and FEED study, which could give a more accurate estimate of the area that would be required.

Overall, from our review of the proposed development, there is sufficient area within the DCO red line boundary for development of a facility to capture both the biogenic and fossil CO_2, which equates to capture of approximately 650,000 tCO_2 annually.

3 Utilisation of CO_2

3.1 Use cases

CO_2 can used as a feedstock for synthesis of several fuels and chemicals. These fuels known as electrofuels (efuels) can be synthesised by reacting CO_2 with hydrogen (H_2) (produced by electrolysis of water using renewable energy) to produce a syngas. This syngas is then upgraded and processed using Fischer-Tropsch (FT) technology to produce a range of efuels. As these fuels do not differ significantly in chemical composition from fossil fuels, they can be used as drop-in fuels in existing infrastructure and end user systems. Furthermore, as the carbon output from combustion of these fuels is considered to be equal to the carbon input from the CO_2 production sources[1], efuels are considered as a route for decarbonisation of hard to abate sectors such as chemical manufacturing, heat and transport. Electro-sustainable aviation fuel (eSAF) is one of the primary fuels under consideration for decarbonisation of the aviation sector through substitution of Jet A1, which is currently primarily produced from fossil fuels.

3.2 Electro Sustainable aviation fuel (eSAF)

3.2.1 Description

The primary route for the production of SAF using CO_2 is through upgrading of syngas by the FT process. An alternative route via upgrading of methanol is currently under development.

For production of eSAF via FT, a syngas produced from the synthesis of CO_2 and H_2 is initially treated in a water gas shift reactor to adjust the ratio of H_2 to CO to the optimal ratio for FT synthesis. The shifted syngas is then treated in a multistep syngas treatment and conditioning system before being discharged to the FT process. Generally, the H_2 and CO mixture is then converted in an FT reactor over a cobalt or iron-based catalyst to produce a synthetic crude oil known as an FT liquid. The raw FT liquid is then distilled to separate the components which are primarily SAF and sustainable diesel.

An alternative SAF production route now being developed by several technology developers including ExxonMobil and TotalEnergies is methanol to Jet. In this process, the syngas produced from the conversion of CO_2 and H_2 is used to synthesise green methanol which is an intermediate product. The green methanol produced is then converted to eSAF through a series of processes including olefin synthesis, oligomerisation and hydrotreating.

Unlike the FT route both CO_2 and CO can be used for synthesis of SAF via Methanol to Jet both processes produce large quantities of heat and as a result heat integration across the various stages is essential for optimised operation and maximum yields of SAF.

3.2.2 Commentary/assessment

Whilst FT synthesis is well established for operation with fossil fuels, the production of eSAF is an emerging technology and no commercial scale plants are in operation. The first commercial scale demonstrator which is reported to have a design capacity of 50,000 t/year is AirPlant One which is being developed by Twelve and is currently under construction in Moses Lake, Washington, USA.

1 Lifecycle analysis will be required on a case by case basis to assess the carbon neutrality of the CO2 used for production of eSAF.

Whilst construction is scheduled for completion this year (2025), details on the project programme have not been published. Consequently, significant development at scale of this technology is required before investment in commercial scale projects can be considered

The production of SAF for use in commercial flights is rigorously regulated by ASTM International and as of July 2023, there were 11 approved pathways several of which include eSAF based on FT synthesis. Whilst methanol synthesis and several of the associated technologies in the Methanol to Jet pathway are established processes, the production of SAF via methanol is not yet an approved route for synthesis of SAF.

Overall, the production of SAF is a nascent technology. Whilst commercial scale production of eSAF is needed due to the global demand for decarbonisation of the aviation sector, based on our experience in this sector we anticipate that reliable long term operation of this technology at scale could be in place around the mid 2030s.

3.3 ePolymer production

3.3.1 Description

CO_2 is a chemical precursor and has been identified as a feedstock for the production of polymers including plastics, foams and resins. Currently, these materials are manufactured by cracking hydrocarbon feedstock such as ethane and propane which are derived from natural gas and crude oil. The intermediate product formed is an olefin (propylene or ethylene) which is then used to make a range of polymers such as polyurethane (PUR), polypropylene (PP), polyethylene (PE), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC) etc. These polymers are used across a range of industries.

CO_2 can also be used by a variety of technologies to produce these polymers. This includes converting CO_2 and hydrogen to methanol, which is then converted to olefins, and by reacting CO_2 with epoxide (a fossil-based raw material) to produce polycarbonates such as polypropylene carbonate (PPC) and polyethylene carbonate (PEC) or polyol; polyols are the building blocks for polyurethane (PUR).

PUR can be made by a copolymerisation process from two monomers. One monomer would be a polyol, and the other would typically be an aromatic isocyanate. Ethylene glycol is a diol, as it has two alcohol functional units, one at either end of the molecule. A diol is the simplest polyol, and ethylene glycol is the second simplest diol, making it a good choice for use in PUR production.

The most produced isocyanate that could be used in polyurethane production is MDI (methylene diphenyl diioscyanate). Ethylene glycol can be synthesised from methanol, which can in turn be synthesised from CO_2 and H_2. The amount of H_2 that would be required alongside CO_2 would be dependent on the chemical route taken and on the overall yield associated with that route.

The co-polymerisation reaction typically occurs under high temperature and pressure. However, new catalysts are being formulated under new research and development to enable operation under low pressure and ambient temperatures. Using CO_2, the energy requirement is about the same as the conventional process using fossil fuel derived chemicals.

3.3.2 Commentary/assessment

The estimated consumption of plastics in the UK is 5 Mt[2] of which nearly 50% is from packaging. The plastics commonly used for packaging are PE and PP. However, there are no known polycarbonates that can replace these materials hence the recommended route is the methanol intermediate route when considering plastics such as PE, PP, PET, PS etc. There is the potential for bio-based polymers produced from biomass and waste to manufacture intermediate materials that can be used in the production of PE, PP, PET etc in the mid-term[3]. These bio-based polymers can compete with the CO_2-derived polymers via the methanol route. A detailed study into the cost of producing these polymers will need to be done to assess the commercial viability of choosing this route.

For the polycarbonates route, PUR is the main focus as it can be synthesised from PPC. PUR is used in building and construction for making foams, coatings, adhesives, sealants and elastomers hence, there is a market for this product. The technology has been demonstrated and used industrially. In 2016, Covestro commenced operations at its facility in Germany which produces 5 kt of polyether polycarbonate polyols which is a PUR precursor. In 2018, Econic started the first demonstration plant in the UK using CO_2 captured from energy from waste. A lifecycle analysis[4] of the emissions from each production process estimated a reduction in emissions by up to 19% when compared with the conventional fossil-based route and a conservation of up to 16% of the fossil resources. This highlights the benefits for using this route.

Globally, 25.8 Mt of PUR were produced in 2022 and this is expected to grow to 31.3 Mt by 2030. There is a demand for this product and with more research and development, the use of CO_2 polyols could expand into other plastics. However, in the short to mid-term, the use of CO_2 for PUR production should be focused on. We recommend the following in considering this utilisation option:

1. engagement with technology developers to understand the current status of the technology;
2. a market study to understand the offtakers for the CO_2-derived polyol or consider further production of a form of PUR; and
3. assessment of the cost of production, energy requirements and space required to determine the suitability of the land available to site a facility for this purpose.

Given the complexity of the process plant associated with making eSAF or ePolymers from carbon dioxide, and the early stage of development of the technology and the risk level associated with it, there may be advantages with shipping CO_2 from NLGEPL off-site for further processing and having a back-up plan in case the agreement to take CO_2 were to fall through.

Yours sincerely,

FICHTNER Consulting Engineers Limited

[redacted]

[redacted]

Calum Bezer
Associate Senior Consultant

C. Andrea Jordan
Lead Consultant

---

2 https://commonslibrary.parliament.uk/research-briefings/cbp-8515/

3 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/799293/SISUK17099AssessingCO2_utilisationUK_ReportFinal_260517v2__1_.pdf

4 https://pubs.rsc.org/en/content/articlelanding/2014/gc/c4gc00513a