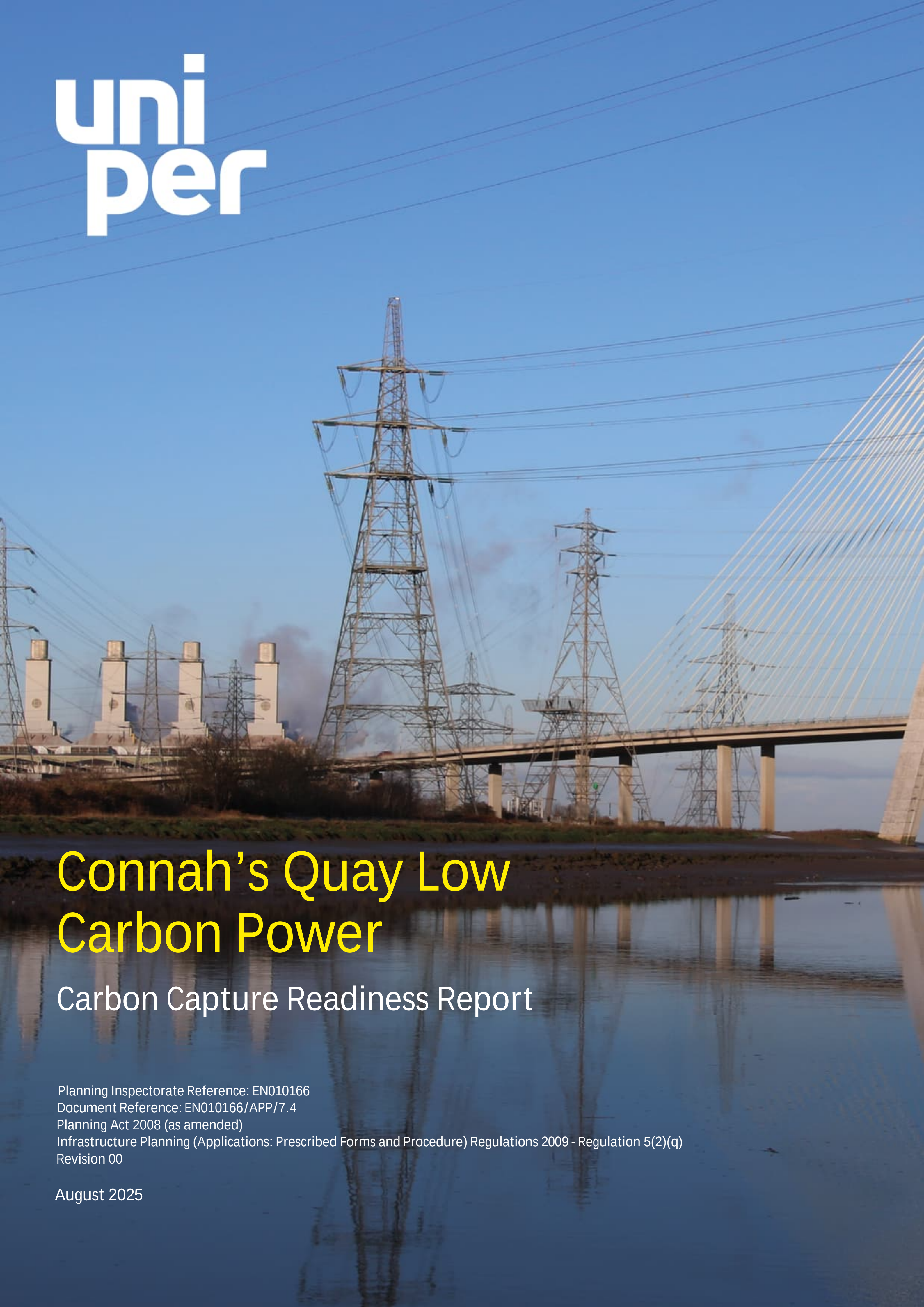

Connah’s Quay Low Carbon Power

Carbon Capture Readiness Report

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Executive Summary

Uniper UK Limited (the Applicant) has made an application (the Application) for a development consent order (DCO) from the Secretary of State (SoS) to authorise the Connah's Quay Low Carbon Power project (the 'Project' and also described as 'the Proposed Development' or as 'CQLCP').

The CQLCP Abated Generating Station would comprise up to two Combined Cycle Gas Turbine with Carbon Capture Plant units (and supporting infrastructure) achieving a net electrical output capacity up to a likely maximum of 1,380 MWe (with CCP operational) onto the national electricity transmission network.

The captured Carbon Dioxide (CO_2) is intended to be exported for safe, long term, geological storage using the HyNet Pipeline and associated CO_2 storage being developed by Liverpool Bay CCS Ltd.

Whilst intended to be built with carbon capture technology from the outset, there is a requirement to demonstrate carbon capture readiness of the Proposed Development, in accordance with the Department of Energy and Climate Change (DECC) November 2009 guidance 'Carbon Capture Readiness (CCR) – A Guidance Note for Section 36 Electricity Act 1989 consent applications.' This guidance also applies to projects seeking Development Consent Orders. Here, this document describes carbon capture technology and a proposed solution to achieve this as part of the CQLCP development.

Following technical assessment, pre-FEED (Front End Engineering Design) and ongoing FEED studies, **the conclusions are that the Proposed Development can be deemed to be Carbon Capture Ready as it meets the CCR conditions that; (a) suitable storage sites are available for CO_2; (b) it is technically and economically feasible to equip the plant with necessary process equipment to capture CO_2; and (c) it is technically and economically feasible to transport such CO_2 to the storage site.**

The main reasons for this are:

- There is sufficient footprint available to install the carbon capture plant.
- There is a credible route off site for the captured CO_2 via a short, repurposed pipeline already in existence (with a very short new build section to connect it to the HyNet CO_2 Pipeline).
- Storage of CO_2 can be delivered by Liverpool Bay CCS Ltd.
- Both the CO_2 storage, and onward CO_2 transport have achieved the consents necessary for construction.
- Economic feasibility is delivered through the Dispatchable Power Agreement, which Uniper are seeking to obtain via the Track 1 expansion process.

1. Introduction

1.1 Purpose and Structure of this Carbon Capture Readiness Report

1.1.1 Uniper UK Limited (the Applicant) has made an application (the Application) for a development consent order (DCO) from the Secretary of State (SoS) to authorise the Connah's Quay Low Carbon Power project (the 'Project' and also described as 'the Proposed Development') which is described at Schedule 1 (Authorised Development) to the **Draft DCO (EN010166/APP/3.1)**, which accompanies the Application and is entitled The Connah's Quay Low Carbon Power Order 202[*] (the Order) **(EN010166/APP/3.1)**.

This report is a Carbon Capture Readiness (CCR) assessment, as required under the Carbon Capture Readiness (Electricity Generating Stations) Regulations 2013 and collates the evidence required, to establish that the CCR conditions are met.

1.1.2 The report first introduces the site and the Proposed Development, before going on to describe what would be involved in the design and execution of carbon capture technology, as is intended to be an integral part of the project. The assessment is undertaken in a manner consistent with the guidance published by DECC (Ref 1) and incorporating the amendments recommended by Imperial College London (Ref 2).

1.2 Description of the Proposed Development

1.2.1 The Applicant is seeking a Development Consent Order (DCO) for the construction, operation (including maintenance) and decommissioning of a proposed low carbon Combined Cycle Gas Turbine (CCGT) Generating Station fitted with Carbon Capture Plant (CCP) and supporting infrastructure.

1.2.2 The CQLCP Abated Generating Station would comprise up to two CCGT with CCP units (and supporting infrastructure) achieving a net electrical output capacity of more than 350 megawatts (MW; referred to as MWe for electrical output) and up to a likely maximum of 1,380 MWe (with CCP operational) onto the national electricity transmission network.

1.2.3 Through a carbon dioxide (CO_2) pipeline, comprising existing and new elements, the Proposed Development would make use of CO_2 transport and storage networks owned and operated by Liverpool Bay CCS Limited, currently under development as part of the HyNet Carbon Dioxide Pipeline project (referred to as the 'HyNet CO_2 Pipeline Project'), that will transport CO_2 captured from existing and new industries in North Wales and North-West England, for offshore storage. The captured CO_2 will be permanently stored in depleted offshore gas reservoirs in Liverpool Bay.

1.2.4 For the purposes of the electrical connection, National Grid Electricity Transmission plc (NGET), which builds and maintains the electricity transmission networks, is responsible for the operation and maintenance of the existing 400 kV NGET Substation.

1.2.5 A description of the Proposed Development, including details of maximum parameters, is set out in **Chapter 4: The Proposed Development** of the

Environmental Statement (ES) (EN010166/APP/6.2.4). At this stage in the development, the design of the Proposed Development incorporates a necessary degree of flexibility to allow for ongoing design development. As such, this report contains some assumptions and statements based on a generic power station and capture plant design (taking account of the flexibility sought in the DCO application and assessed in the ES), rather than providing detailed information on any particular proprietary capture technology.

1.2.6 Schedule 1 to the **Draft DCO (EN010166/APP/3.1)** splits the Proposed Development into 13 Work Nos. and also includes Site Wide Works, which may be carried out in connection with the construction of Work Nos. 1 to 13, as follows:

- **Work No. 1** – A CCGT electricity generating station of more than 350 MW with CCP and ancillary buildings and structures within the Main Development Area (MDA). This comprises (a) up to two combined cycle gas turbine plants; (b) up to two carbon dioxide (CO_2) capture plants; (c) plant cooling and utilities infrastructure; (d) a natural gas reception facility; (e) a carbon dioxide interface facility; (f) administration, control room and stores; (g) demolition of existing buildings and structures including the existing gas treatment plant; (h) demolition of the existing ENI Above Ground Installation (AGI); and (i) various ancillary works.
- **Work No. 2** – Infrastructure connection works, including:
  - works to connect to an existing high pressure gas supply pipeline running within the existing power station site;
  - underground and potentially overground electrical cables and control system cables to connect Work No. 1 to switch disconnectors;
  - new connections and improvements to existing water pipelines between Work No. 1 and the supply point north of Kelsterton Road; and
  - cooling water connections from Work No. 3 to Work No. 1.
- **Work No. 3** – Water supply connection works to provide cooling water to Work No. 1 and discharge of used cooling water and treated process water. This Work comprises works to the existing cooling water supply pipelines between Work No. 1 and the River Dee and the existing intake structures within the River Dee between the existing concrete manifold and existing protection structure.
- **Work No. 4** – Temporary construction and laydown areas.
- **Work No. 5** – Construction of a surface water discharge.
- **Work No. 6** – Electrical connection works for the export and import of electricity, including works within the existing National Grid substation.
- **Work No. 7** – Construction of an underground Carbon Dioxide (CO_2) pipeline approximately 422 metres in length between Work No. 8 and the existing repurposed natural gas pipeline (to be used for CO_2).
- **Work No. 8** – Modification of an AGI at Flint to connect the CO_2 pipeline into the HyNet CO_2 Pipeline.

- **Work No. 9** – The creation and use of a temporary logistics and construction compound for the use during the construction.
- **Work No. 10** – Works to provide site access.
- **Work No. 11** – Temporary accommodation works to facilitate haulage route access between the Port of Mostyn and Work No. 1, including the temporary removal of a gate and fence adjacent to the railway and subsequent reinstatement.
- **Work No. 12** – Re-establishment and use of waterborne transport offloading facilities at Connah's Quay North (known as the Corus Jetty) south of Flintshire Bridge and temporary accommodation works to facilitate the haulage route on existing roads between Connah's Quay North and Work No. 1.
- **Work No. 13** – Landscaping, biodiversity enhancement measures and boundary treatment.
- **Site Wide Works** – Further associated and ancillary development comprising such other works or operations as may be necessary or expedient.

1.3 Description of the Site and Order Land

1.3.1 The Proposed Development's MDA is located approximately 0.6 kilometres (km) north-west of Connah's Quay in Flintshire, north-east Wales. The MDA is centered at national grid reference 327347, 371374. The Order Limits for the Proposed Development lie entirely within the Flintshire County Council (FCC) administrative area.

1.3.2 The Order Limits, as shown in in **Figure 3.1: Order Limits (EN010166/APP/6.3)**, encompass a total area of approximately 105 hectares (ha).

1.3.3 Around 86.2 ha of the Order Limits comprises the 'Construction and Operation Area', comprising the MDA, construction areas and connection corridors necessary for the construction and operation of the Proposed Development shown in **Figure 3-1: Order Limits (EN010166/APP/6.3)**. A further 18.8 ha of land is included for the 'Accommodation Works Areas', comprising areas of works required to facilitate the movement and temporary storage of Abnormal Indivisible Loads (AIL) during construction of the Proposed Development.

1.3.4 The Order Limits include the existing Connah's Quay Power Station site, which is owned and operated by the Applicant, and adjacent land for the purposes of facilitating connections to the Proposed Development for gas, electricity, water and other necessary infrastructure.

1.3.5 The town of Connah's Quay is located to the south-east of the existing Connah's Quay Power Station and the MDA, immediately beyond the A548 and the North Wales Main Line railway. The area to the south-west of the MDA is mainly used for pastoral agriculture with some arable agriculture while the area to the north-west of the MDA is a nature reserve within several statutory designated sites.

1.3.6 The Order Limits include the following areas:

- The Construction and Operation Area, including:
  - the MDA, which is an area of around 56.5 ha that includes operational parts of the existing Connah's Quay Power Station and agricultural fields. Areas of the MDA would be developed for the proposed CCGT and CCP and used for temporary laydown areas during construction. An existing 400 kilovolt (kV) high-voltage overhead electrical transmission line crosses the MDA. It is bordered generally to the north by the Dee Estuary, to the east by the existing National Grid Electricity Transmission plc (NGET) 400 kV Substation, and to the south by the North Wales Main Line railway;
  - the Repurposed CO_2 Connection Corridor is an area between the south-west corner of the MDA and the north-east corner of the Proposed CO_2 Connection Corridor. It comprises around 4.3 ha and is largely agricultural fields and hedgerows. It follows the route of an existing underground gas pipeline and forms approximately 3 km of an overall 27 km pipeline route between the existing Connah's Quay Power Station and Point of Ayr Gas Terminal to the north-west;
  - the Proposed CO_2 Connection Corridor mirrors the area consented for the Flint AGI and pre-existing (by time of construction) CO_2 Pipeline works within the HyNet CO_2 Pipeline Project[1]. It comprises around 6.2 ha within which a new CO_2 export pipeline approximately 422 m in length for the Proposed Development would be constructed linking the Repurposed CO_2 Connection Corridor at one end, with the Flint AGI at the other end. Modifications to the Flint AGI would also take place within this corridor;
  - the Water Connection Corridor is an area of around 1.6 ha which includes the existing abstraction and discharge infrastructure for cooling water sourced from the River Dee for the existing Connah's Quay Power Station. It includes both intertidal mudflat and saltmarsh habitats of the Dee Estuary and the River Dee itself. The Proposed Development will utilise the existing Connah's Quay Power Station abstraction and discharge infrastructure for re-use with some refurbishment and additions;
  - the Electrical Connection Corridor is an area of around 3.4 ha which includes the existing electrical export transmission cable(s) that interface with the MDA and the existing NGET 400 kV Substation;
  - the Construction and Indicative Enhancement Area (C&IEA) is an approximate 12.6 ha area of vacant land under the Applicant's ownership south-east of the MDA, which currently comprises derelict hardstanding with scrub / grass vegetation, open grassland and small trees. Following use during construction as a laydown area, it may be used for biodiversity mitigation and / or enhancement;
  - the MDA Access Works Area comprises the existing Kelsterton Road, including a bridge over the North Wales Main Line railway, and part of a former junction between the A548 and Kelsterton Road. This area

[1] Consented under The HyNet Carbon Dioxide Pipeline Order 2024, https://www.legislation.gov.uk/uksi/2024/436/contents (accessed 20 April 2025).

comprises around 0.2 ha of existing hardstanding with small areas of roadside, kerbs, trees and grass;

  - the access to C&IEA would be provided during construction to and from the MDA via an existing hard standing internal access road;
  - the alternative access to MDA is an existing hardstanding road that runs from the B5112 towards the Electrical Connection Corridor beneath the A548 Flintshire Bridge, before intersecting with the access to C&IEA; and
  - the Surface Water Outfall is the area adjacent to the northern extent of the MDA, including and surrounding the existing artificial outfall for surface water drainage (the 'Existing Surface Water Outfall') from the existing Connah's Quay Power Station into the Dee Estuary; and

- The Accommodation Works Areas, including:
  - the A548 from Port of Mostyn to Greenfield follows an existing highway along the A548 between the entrance to the Port of Mostyn and the village of Greenfield and the immediate entrance of the existing Port of Mostyn;
  - the Tir Glas Roundabout on the A548 between Greenfield and Whelston;
  - the A548 through Flint to Chester Road Roundabout follows an existing highway along the A548 through Flint and includes the Chester Road roundabout;
  - the AIL Access comprises a section of the A548 Chester Road adjacent to the MDA Access Works Area and a wooded verge on Kelsterton Road adjacent to the Kelsterton Road / A548 Chester Road;
  - the Connah's Quay North Accommodation Works comprises the existing jetty at Connah's Quay North, including marine and terrestrial components, and the access road from North Road/River Road. The marine components comprise a small section of the Dee Estuary and existing jetty infrastructure (including a piled concrete retaining wall). The terrestrial component comprises hard standing areas and some but limited areas of vegetation; and
  - the North Road to the A548 comprises North Road from the entrance to Connah's Quay North to the A548 Weighbridge Road roundabout.

1.4 Demonstrating Capture Readiness

1.4.1 In November 2009, UK government published guidance on CCR (Ref 1) intended to apply to applications for power stations with an electrical generating capacity at or over 300 MW and of a type covered by the Industrial Emission Directive 2010. Applicants should submit the required assessments demonstrating CCR as part of their Development Consent Order application.

1.4.2 The guidance explains the level of information required by applicants in demonstration of CCR when applying for permission to build a qualifying power station under a Development Consent Order (DCO).

1.4.3 Article 36 of the Industrial Emission Directive requires that the technical and economic feasibility of fitting carbon capture equipment and of the transport of CO_2, together with the availability of CO_2 storage sites, should be assessed by the Applicant and consenting body during the process of deciding whether to grant an operating or construction licence for any new Power Station with electrical outputs at or over 300 MWe and of type covered by the Industrial Emission Directive. This requirement remains in place in the United Kingdom despite having left the European Union through the Environmental Permitting (England and Wales) Regulations 2016 .

1.4.4 If the consenting authority considers that it is technically and economically feasible for a power station to be retrofitted with CCS technology, they must require suitable space to be set aside for the future retrofit of carbon capture equipment. For developments such as CQLCP, that are intended to be equipped with carbon capture from the point at which they are constructed, it is still required that the DCO submission includes a Carbon Capture Readiness report.

1.4.5 The guidance requires that the report outlines:

- that sufficient space is available on or near the site to accommodate carbon capture equipment in the future;
- the technical feasibility of retrofitting their chosen carbon capture technology;

1.4.6 that a suitable area of deep geological storage offshore exists for the storage of captured CO_2 from the proposed power station;

1.4.7 the technical feasibility of transporting the captured CO_2 to the proposed storage area; and

1.4.8 the likelihood that it will be economically feasible within the power station's lifetime, to link it to a full CCS chain, covering retrofitting of capture equipment, transport and storage.

1.4.9 In addition, if applicants' proposals for an operational carbon capture plant involves the use of hazardous substances, they may be required to apply for Hazardous Substances Consent (HSC).

1.4.10 It is important to consider in the context of CQLCP that paras 98 and 99 of DECC 2009 state that "*it is possible that some applicants for new power stations at or over 300 MWe may believe they are unlikely in the future to move to CCS because they would plan to switch to using hydrogen as a fuel (thereby reducing CO2 emissions to zero and obviating the need for any carbon capture)"*. Whilst a hydrogen connection to site may become an option to achieve carbon reduction at some point in the future, and one that avoids the need for on-site capture and transport of CO_2 in the future, DECC believed that there is insufficient certainty in such a possibility to avoid the need to demonstrate CCR via on-site means currently. Therefore, "*as a minimum that the specified technical and economic CCR assessments on storage, transport and retrofitting should be done. Also, given the uncertainties about whether the volumes of hydrogen needed would be commercially available at the unknown point when it might be required, the Government will still require such applications to demonstrate CCR by completing these assessments and by ensuring suitable space is left available on site to retrofit CCS equipment".*

Options submitted in the CCR report must describe feasible technologies that decarbonise the fuel or waste products from the combustion process, at that site, rather than relying on some future, unspecified, over the fence treatment.

1.4.11 The latest version of NPS EN-1, published in April 2025, includes new draft policy at para 2.4.10 that states the following: "*From February 2026, new gas plants will need to be built 'decarbonisation ready', demonstrating they are compatible with carbon capture, utilisation and storage or able to convert to hydrogen powered generation*". Whilst this is recognised as an option for new build plant, it is the intention that for the CQLCP development, the focus of this document will be on CCR and not decarbonisation readiness, with the same requirements in place to demonstrate this for the new combustion plant as before.

1.5 The Applicant

1.5.1 The Applicant is a UK-based company, wholly owned by Uniper SE (Uniper) through Uniper Holding GmbH. Uniper is a European energy company with global reach and activities in more than 40 countries. With around 7,500 employees, the company makes an important contribution to security of supply in Europe, particularly in its core markets of Germany, the UK, Sweden, and the Netherlands. In the UK, Uniper owns and operates a flexible generation portfolio of power stations, a fast-cycle gas storage facility and two high pressure gas pipelines, from Theddlethorpe to Killingholme and from Blyborough to Cottam.

1.5.2 Uniper is committed to investing around €8 billion (~£6.9 billion) in growth and transformation projects by the early 2030s and aims to be carbon-neutral by 2040. To achieve this, the company is transforming its power plants and facilities and investing in flexible, dispatchable power generation units. Uniper is one of Europe's largest operators of hydropower plants and is helping further expand solar and wind power, which are essential for a more sustainable and secure future. Uniper is gradually adding renewable and low-carbon gases such as biomethane to its gas portfolio and is developing a hydrogen portfolio with the aim of a long-term transition. The company plans to offset any remaining CO_2 emissions by high-quality CO_2-offsets.

2. Design Basis

2.1.0 The basis for this assessment has been the Pre-FEED (Front End Engineering Design) undertaken as part of Uniper's project development. It takes into account the physical layout of the proposed plant as well as the broader context of its location and proximity to other low carbon infrastructure being provided in the region, most importantly the HyNet CO2 pipeline project, being developed by Liverpool Bay CCS Limited (LBCCS).

2.1.1 Given the intention for the Proposed Development to be supported through a Dispatchable Power Agreement (Ref 3), and the need for that to employ high Technology Readiness Level capture processes to generate power and capture carbon, there has been no consideration here of novel technologies. Instead, this assessment has been completed on the basis of the post combustion capture of CO2 from the flue gas of the CCGT using a monoethanolamine (MEA) solution. This represents an archetype of the most readily deliverable decarbonisation option available for a large combined cycle natural gas fired power plant.

3. Post Combustion Carbon Capture

3.1 Overview

3.1.1 Low partial pressure of CO_2 in the gas turbine exhaust, typically of the order of 50 mbar(a), combined with very large volumes of flue gas to be treated, imposes limitations on currently available carbon capture technologies suitable for treating gases from CCGT units. Despite significant research efforts over recent years into alternative capture technologies, such as membrane separation and oxyfuel combustion, chemical absorption by amines or similarly acting materials remains the only process developed to a sufficient level of maturity to offer a credible technological solution, and to satisfy the requirements of the Dispatchable Power Agreement (Ref 3). As such, this is the basis of this document.

3.1.2 A generic, amine based, post-combustion capture process relies on transferring CO_2 from the gas phase into a liquid solvent in a counter-current absorption column with simultaneous exothermic reaction forming a semi-stable compound. The CO_2 laden solvent is transferred to a regeneration or stripping column, where the process is reversed by applying heat to release the captured CO_2. Regenerated solvent is then returned back to the absorption column. Solvent regeneration is assisted by stripping steam generated in the reboiler, which is condensed out and returned to the stripper as a reflux stream. The process requires large quantities of steam, which in the case of a power plant, would usually be supplied from the host "power island", thus reducing the plant overall efficiency and increasing its operating costs. Depending on the selected transportation and storage options, captured CO_2 is usually dehydrated and compressed to a required pipeline pressure for transport to a storage site or a liquefaction facility. The capture plant is referred to here as the "capture island" or "CCS island".

3.2 MEA Capture Process "CCS Island"

3.2.1 Alkanolamine compounds have been considered as solvents of first choice for chemical absorption of CO_2 for some time. Whilst the secondary and tertiary amines, such as DEA (diethanolamine) or MDEA (methyl-diethanolamine), found a successful application in CO_2 and H2S (hydrogen sulphide) removal from raw natural gas under high pressure conditions, the primary amines, such as MEA (monoethanolamine), have been used in low pressure applications, such as recovery of CO_2 from steam reformer exhaust for urea production. That type of application is characteristic of the process conditions present in the flue gas of the Proposed Development from which CO_2 is to be captured.

3.2.2 MEA has several advantages compared to other amine solvents. It has high absorption rates for CO_2, reasonable thermal stability and relatively low production costs. On the downside, MEA has a high thermal regeneration requirement, which adversely impacts on the efficiency of the power plant . It also exhibits high corrosion rates for conventional steel, particularly at high CO_2 loading rates, requiring the use of corrosion inhibitors or expensive alloy materials. The solvent is also prone to significant thermal and chemical degradation in the presence of oxygen, SOx and NOx. The reaction with SO_2 leads to formation of heat stable sulphate salts (HSS), which gradually accumulate in the system and have to be periodically removed by solvent reclaiming. This consists of evaporating MEA from the solution and filtering out the concentrated salts as a waste product. This reaction is unlikely to be a significant issue in treating flue gas from a CCGT unit such as those in the Proposed Development, as the fuel gas contains only trace quantities of sulphur compounds, and therefore the flue gas will contain only trace amounts of SOx. However, the side reactions with NO_2 component of NOx are known to occur and have to be taken into consideration in CCGT applications.

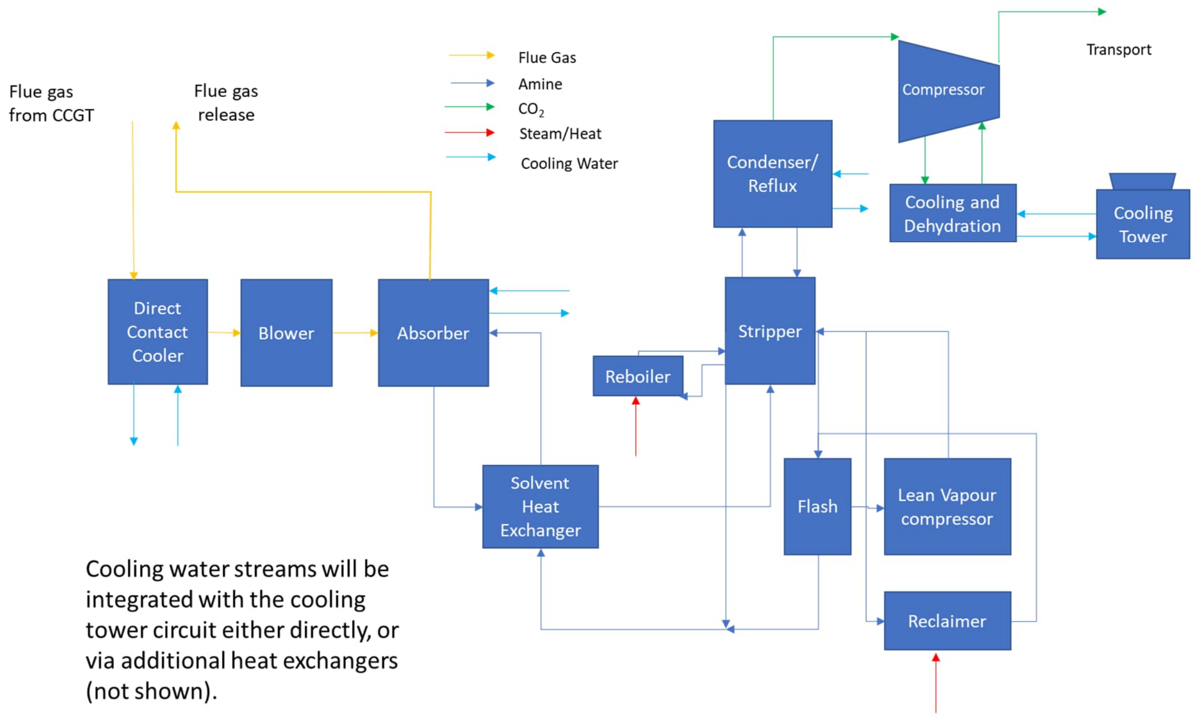
3.2.3 Despite these drawbacks, the MEA process remains one of the leading candidates for post combustion carbon capture applications in thermal power plants due to its relative simplicity, operating flexibility and solvent availability. For these reasons, the MEA process has been selected in this document as a benchmark process for evaluating CCR requirements. Nevertheless, Uniper is investigating proprietary solvent technologies during the FEED stage, a process which is currently ongoing.

3.3 Process Configuration

3.3.1 The process configuration for an amine capture plant treating exhaust gas from a CCGT unit is shown schematically in **Figure 1**. The main components of the capture plant are listed below and described in the following paragraphs:

- Exhaust gas pre-treatment section
- Absorption section
- Stripping section
- Solvent reclaiming section
- Steam and condensate system
- Cooling system
- Compression system.

Figure 1: Carbon Capture Plant configuration



Flue Gas Pretreatment and Cooling

3.3.2 Hot flue gas exiting the heat recovery steam generator HRSG unit has to be significantly cooled down before undergoing CO_2 capture in the amine absorber. This is carried out in the direct contact cooler (DCC) by quenching the gas stream with a cooled recirculating water stream. The circulating water leaves at the bottom of the DCC column and is returned back to the top of DCC via the DCC water cooler. Flow control is such as to ensure the intended flue as temperature at the inlet to the absorber. A slip stream is diverted from the circulating water downstream of the pump to the water filter to remove particulate matter – noting that due to the very clean flue gas from a gas fired unit, this functionality may not be necessary. Excess water is continuously purged from the DCC cooling water loop to maintain the water balance in the system. This water is of good quality and, if treated appropriately, may be used elsewhere in the power plant.

3.3.3 The DCC unit may also serve an additional purpose of removing sulphur oxides (if present) to ppm levels by scrubbing the gas with caustic soda solution. Since the UK natural gas contains very low levels of sulphur, from which sulphur oxides might form in combustion, there may be no need for a desulphurisation stage to be provided.

3.3.4 To overcome the pressure drop through the gas path presented by the DCC and the amine absorber a Booster Fan (BUF) may be installed downstream of GGH to avoid imposing back pressure on the HRSG and gas turbine (GT) units. This is as the typical allowable back pressure for the GT is not sufficient to overcome the draft losses associated with the passage of flue gas through the capture plant.

3.3.5 The BUF is a major consumer of electrical energy and requires around 11.6 MWe of power in normal operation.

CO2 Absorption

3.3.6 Flue gas enters the bottom of the absorber column and flows upward through the structured packing sections where it is contacted with the lean MEA solvent. Since the resulting chemical reaction is exothermal (heat is given off), an absorber intercooler may be is installed in the lower section of the column to remove the heat of reaction and maintain the solvent temperature within the design limits. This helps to achieve high CO_2 loading in the rich solvent, which reduces the solvent circulation rate and the energy requirement of the process.

3.3.7 Treated gas from the absorption section enters a wash section at the top of the absorber where residual MEA vapour is captured by a counter-current water stream. Wash water is circulated by a wash water pump and cooled in the wash water cooler.

3.3.8 Demineralised water may be added at the absorber top to assist in fine removal of solvent vapours and entrained liquid droplets from the exiting gas and to maintain the water balance in the system. Excess wash water is filtered through a wash water filter and combined with the lean solvent entering the top of the absorber.

3.3.9 In order to help control the release of solvent components, and reaction by-products, an acid wash may also be used to clean the flue gas further prior to release.

3.3.10 The temperature of the treated gas exiting the top of the absorber is maintained in the approximate range of 35° to 40°C, in order to reduce the losses of both the solvent and the water vapour in the treated gas.

3.3.11 The treated flue gas exiting the absorber is virtually at its dew point and may require some reheating to assist in plume dispersion and the achievement of air quality requirements.

Solvent Regeneration (Stripping)

3.3.12 The CO_2 rich solution leaves the bottom of the absorber and is pumped by a rich solvent pump to the stripper column via the cross-stream heat exchanger which preheats it by the lean solvent exiting the reboiler. The hot solvent enters the below the wash section of the column and flows downwards through the structured packing, where it is contacted with process steam which drives the CO_2 out of the solution. The lean solvent collects on the bottom chimney tray and is sent to a reboiler to be heated up to its boiling point by a desuperheated steam supply taken from the power island.

3.3.13 The recovered CO_2 enters the wash section of the column, where vaporised and entrained MEA is recovered by contact with a reflux stream from the overhead accumulator and returned back to the main section of the stripper. The product stream containing only CO_2 and water vapour is cooled and water condensed out in the overhead condenser. The two-phase mixture is then separated in the accumulator and a fraction of process water is returned to the wash section of the stripper as a reflux. The reflux flow rate is controlled to maintain the minimum liquid level in the accumulator. The remaining water can then be sent elsewhere in the process if needed to maintain vessel water levels.

3.3.14 The CO_2 product is sent to the compression and dehydration unit.

3.3.15 One means of improving the overall energy efficiency of the process is to employ lean vapour recompression. In this scheme, lean solution from the stripper undergoes a pressure drop through a control valve and is flashed in a vessel at around atmospheric pressure. The flashed vapour is returned to the stripper by the lean vapour compressor to provide additional stripping steam to that generated in the reboiler. Whilst not an essential element of post combustion amine capture plant, lean vapour recompression reduces the heat load on the reboiler and improves the overall energy efficiency, although it should be said that this comes at the expense of the increased capital and associated operating cost of the compressor package.

3.3.16 The hot lean solvent from the flash drum is pumped by the lean solvent pump via the solvent cross-stream heat exchanger back to the absorber.

3.3.17 To remove impurities from the circulating solvent, a slipstream of the cooled solvent is routed to a lean solvent filtration package, to remove soluble impurities, and a fines filter to remove any carbon particulate carryover from the carbon bed. The filtered solvent returns to the main lean solvent line.

Solvent Reclaiming

3.3.18 The removal of heat stable salts (HSS) from hot MEA solvent is carried out in the reclaimer by reaction with diluted sodium hydroxide or sodium carbonate (soda ash) solution. The operating conditions for this reclaimer vessel are different to that of the stripper column in order to control, as best possible, thermal degradation of the treated solvent stream.

3.3.19 The reclaiming system operates intermittently and over prolonged periods of time. The exact reclaiming scheme is proprietary to process suppliers and, whilst it is anticipated that the reclaiming need for carbon capture in a gas fired CCGT power plant such as the Proposed Development is likely to be lower than on units with greater sulphur component contents it is, nevertheless, expected that a reclaiming unit will be required due to side reactions with oxygen, NOx and other flue gas impurities.

3.3.20 The reclaimer receives a slip stream of hot lean solvent from the bottom of the stripper mixed with a caustic solution supplied from an injection package. The combined stream then enters the reclaimer vessel itself. Here, the majority of the solvent is flashed off. The concentrated solvent is circulated through a heater which maintains the drum temperature at the required level. The vapour stream exits the reclaimer flash drum through the reclaimer surge drum before being sent to the absorber.

3.3.21 A liquid bleed from the reclaimer containing highly concentrated HSS and degradation products exits the system. Due to the intermittent and small amount of the flow, the reclaimer waste is likely to be sent off site to a specialised waste disposal company.

Steam and Condensate System

3.3.22 Steam needs to be extracted from the power island to supply the solvent stripper reboiler. In principle, this can be from a number of locations on the steam cycle of the plant. However, it is commonly proposed to be taken from the crossover between the intermediate pressure and low pressure steam turbine sections. This is as the steam quality best matches that required by the capture plant at this location, and the efficiency penalty of the extraction is minimised in comparison with other extraction points. Nevertheless, before entering the reboiler, the steam is first desuperheated to slightly above its saturation temperature by spraying it with condensate. This is to maximise efficiency in the capture plant.

3.3.23 Steam flow is controlled to achieve the desired lean solvent loading at the exit from the stripper. The condensate leaving the reboiler is collected in the reboiler condensate drum and then returned back to the power island. This condensate can also be used for desuperheating where this is required in the process.

CO_2 Compression

3.3.24 The CO2 stream exits the capture plant at just above atmospheric pressure and at elevated temperature. It is assumed here that this will be compressed on site to 42 barg for entry to the HyNet CO_2 Pipeline System.

3.3.25 The compressor on site will compress the CO_2 through multiple stages to the desired pressure, and include inter-stage coolers and knockout vessels to remove condensed water. Following compression, the CO_2 stream has to undergo dehydration to ppm levels (molecular sieves are assumed here) and also oxygen removal (through catalytic reaction with small volumes of hydrogen). Final cooling will also be required before entering the export pipeline. This low moisture and oxygen content is required to mitigate the risk of pipeline corrosion in the downstream transport system, and also to minimise the risk of any problems at the injection location.

3.3.26 The CO_2 compressor is a major power consumer in normal operation consuming around 12.5 MWe.

3.3.27 Overall, additional electrical consumption across the whole plant associated with the capture and conditioning of CO_2 is around 50 MWe (excluding duty associated with cooling fans in the cooling system as that is not directly attributable solely to capture). This figure would be expected to vary significantly as detailed design through FEED develops.

Cooling System

3.3.28 The capture plant has substantial cooling requirements, with the main demands for this being the DCC, absorber intercooler, stripper overhead condenser and the CO_2 compression train. This cooling demand will be integrated with the overall cooling demand of the power island.

4. Space Requirements

4.1.0 To demonstrate carbon capture readiness there must be sufficient footprint available and set-aside for the future installation of capture plant. Although this land does not need to be owned currently by the Applicant, there is the need for some control to be held over it such that it remains available for future use. In the case of the Proposed Development, the plant is to be built with carbon capture from the outset, and therefore land does not need to be set aside, as it will be used from the outset.

4.1.1 A calculation of the footprint required for a capture plant has been made based on work undertaken for the IEA GHG and as amended by Imperial College London (2010). This work is intended to be used for plant demonstrating carbon capture readiness, rather than being built with carbon capture from the outset. As such, it is challenging to apply these assumptions to the Proposed Development. However, using the maximum exported power from the Proposed Development, and the assumed plant efficiency, allows an equivalent thermal input to be derived. Then, using the efficiency of a hypothetical unabated CCGT power plant (62% as used in the Dispatchable Power Agreement as the unabated counterfactual) this gives an approximate unabated power output of 850 MW per unit. On this basis, a land area of 7.2-8.1 ha would be required per carbon capture unit. This equates to 14.5.-16.2 ha for the two units proposed.

4.1.2 An indicative plant layout for both units comprising the the Proposed Development is presented in the Figure 4-1: Indicative Site Layout – Single Absorbers (EN10166/APP/6.3). This shows that the development covers approximately 16 ha used for the power island and associated capture island, and approximately 11 ha set aside for construction laydown and contractor's compounds.

4.1.3 Whilst the area proposed is slightly less than that indicated by the Imperial College methodology, it is important to consider two mitigations. The first is that it is noted by Imperial College there is scope to reduce the required footprint by a greater amount when taking into consideration advances in technology and layout optimisation. Specifically, "there appears further scope to reduce the land foot print estimate for a CCGT with post-combustion capture by up to a total reduction of about 50%...considering technology advances and with layout optimisation (e.g. assuming one capture train per GT, or three-to-two". The Proposed Development has undertaken pre-FEED and is currently completing two FEED studies. As such, the level of engineering definition is far greater than would be the case on a typical project type for which the guidance was written (that is, with no immediate intention to install carbon capture). The second mitigating factor is that the Proposed Development is being designed to be fitted with capture from the outset, and the layout is being optimised for it. Furthermore, there is use of shared equipment and buildings between the units, and with the existing Connah's Quay Power Station, further reducing the required land take.

4.1.4 In conclusion, it is considered that the need to demonstrate sufficient availability of land for the Proposed Development is met.

5. Visual Impact

5.1.0 The capture plant items which will be the highest aspects of Proposed Development and therefore will have the greatest visual impact on the Connah's Quay site are the:

- Absorber with associated chimney stack;
- Stripper column; and
- Direct contact cooler.

5.1.1 These are in addition to the tall structures associated with the power island, most notably the:

- CCGT buildings; and
- HRSG chimney stack.

5.1.2 Further information on building and structures is presented in the **Maximum Parameters (Site Layout and Elevations) (EN10166/APP/2.5)**.

6. Carbon Dioxide Export

6.1.0 The Proposed Development is assumed to be operational 24 hours a day, 7 days per week for 30 years. Information regarding maintenance schedules is not currently available, therefore running hours are assumed to be approximately 8,760 hours per year. This has been adopted as a worst-case scenario for assessing the CO_2 storage capacity required, and is in common with the approach used in **Chapter 20: Climate Change of the Environmental Statement (ES) (EN010166/APP/6.2.20)**.

6.1.1 GHG emissions attributed to fuel-use onsite across the Proposed Development's operation have been based on the assumption of both units operating at full power output for the period of the assessment. This is taken from information used in the pre-FEED and equates to 505 tph (tonnes per hour) of CO_2 captured (at 95% capture rate), 4.4 mtpa (million tonnes per annum) (132 mtCO_2 across a 30 year operational life). It is important to recognise that this is a high estimate of the CO_2 captured, and for which storage is required. The actual volume will be less than this due to the plant being designed to respond to demand from the National Grid, meaning that sometimes it will operate below full load, or not be generating electricity at all (and therefore not capturing CO_2 needing to be stored).

6.1.2 For sizing of equipment, the export route needs to be able to accommodate both units, even where in phased development one unit comes on stream before the second.

6.1.3 In principle, the following options are available for off-site transport of CO_2:

6.1.4 Option 1: liquefaction of CO_2 and road transport off-site. This involves compression and cooling of the captured CO2 on site such that it's phase is changed from a gas to a liquid. This approach may be most appropriate for small scale, industrial, capture units or where the final user of the material is nearby and requires CO_2 in that form. However, for Connah's Quay Low Carbon Power this would require large numbers of road traffic movements to move the material from site, and is therefore not considered to be feasible.

6.1.5 Option 2: pipeline transport of supercritical CO_2 off-site. Here, the captured CO_2 is compressed to high pressure, perhaps 100 bar or more, such that it is neither a gas or liquid, but a supercritical fluid. This may be the most feasible option for capture plant in relatively remote locations.

6.1.6 Option 3: pipeline transport of gaseous CO_2 for liquefaction elsewhere. In this option, CO_2 is captured and compressed at the Connah's Quay site, with transportation via a dedicated pipeline to a coastal location, where it will be liquefied and temporarily stored. This storage facility will be used to load CO2 onto transport vessels of tens of thousands of tonnes capacity for transportation to geological storage sites able to receive CO_2 in this form .

6.1.7 Option 4: pipeline transport of compressed and conditioned gaseous CO_2 for further compression and subsequent storage off-shore in abandoned oil or gas fields via new or existing wells. This would involve compression of the captured CO_2 and then transport off-site. At, another location CO_2 is further compressed for transport off shore.

6.1.8 Overall, Option 4 is favoured, as the Connah's Quay site location is served by a short pipeline connection that can be reutilised to flow gaseous CO_2 and allow connection to the HyNet CO_2 pipeline project at the proposed Flint AGI. That development has already been granted development consent, and is being developed by Liverpool Bay CCS Limited (LBCCS).

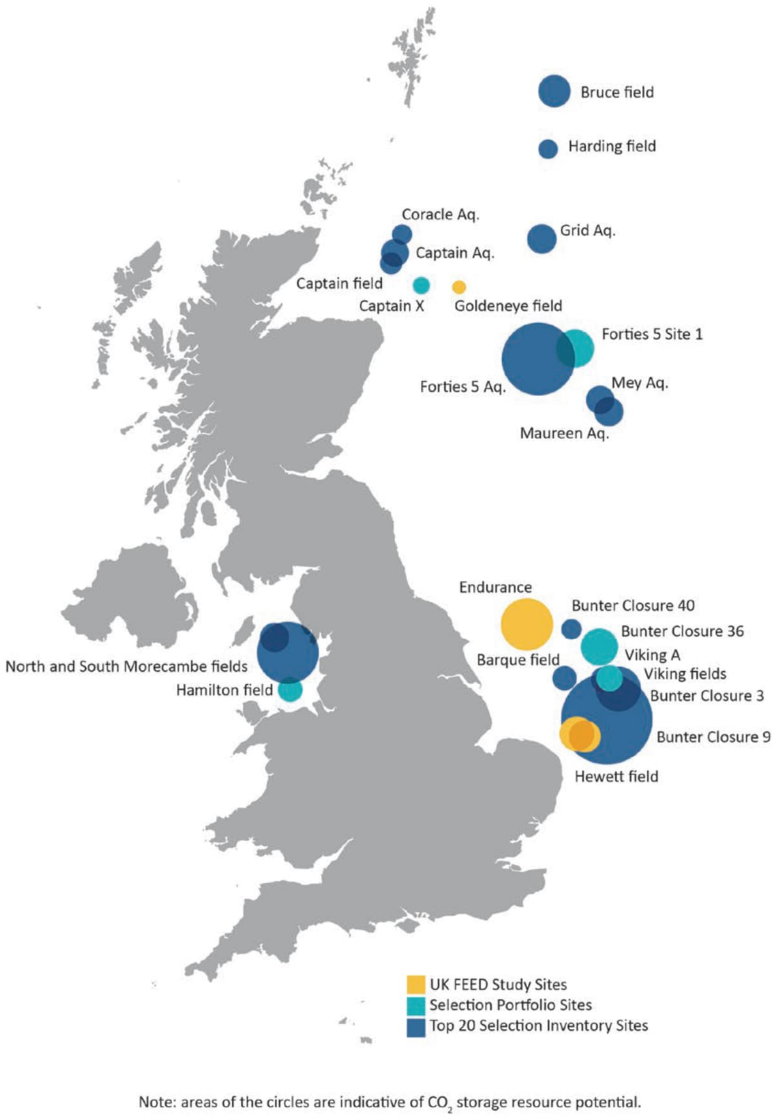
7. Storage Location of CO_2

7.1.1 To demonstrate Carbon Capture Readiness it is necessary to demonstrate that there is the potential to store the volume of CO_2 that the Proposed Development will generate during its operating phase when carbon capture is deployed.

7.1.2 This generally means identifying a possible storage area, including delineating the geographical extent of that area, and identification within that area of at least two oil or gas/gas condensate fields (or saline aquifers) listed in the range of geological formations identified as "viable" or "realistic" for CO_2 storage. This is based on the suitability of areas and fields/aquifers based on the 2006 Department of Trade and Industry (DTI) study or other similarly authoritative source(s).

7.1.3 The figure below is a summary of sites from the UK storage appraisal project the Energy Technologies Institute by Pale Blue Dot (Ref 4). This is more recent than the previously referred to study for DECC.

Figure 2: UK Storage Appraisal Project Selected Sites (Pale Blue Dot, 2016)



7.1.4 For projects situated in North Wales, such as the Proposed Development, the Hamilton field, and North and South Morecambe fields are the nearest and most obvious stores to choose for storage. The Hamilton field, as part of the Liverpool Bay CCS development plans to be able to accommodate up to 10 mtpa (initially 4.5 mtpa) of CO_2 injection from emitters in the HyNet pipeline system, and over 100 mtpa of CO_2 in total (125 mtpa stated in the report for by Pale Blue Dot). Therefore, in practical terms, the Hamilton based Liverpool Bay CCS scheme can accommodate the CO_2 produced by the Proposed Development. However, should it become full, there are options for store expansion in the region to connect into much larger storage fields North and South Morecambe. Between them it is stated that they represent approximately 1 gigatonne of CO_2 storage potential.

7.1.5 Whilst the intended storage capacity of the Liverpool Bay CCS project does not meet the estimate set out in Section 7 of the CO_2 likely to be produced through the operating life of the Proposed Development, the expansion opportunities around the proposed store, combined with the acceptance that less CO_2 will be produced from the Proposed Development than the assessment above suggests, it is deemed that the availability of adequate storage capacity is demonstrated.

7.1.6 Under paragraph 83 of the Carbon Capture Readiness guidance (DECC, 2009) periodic reviews of carbon capture readiness report are required. Paragraph 85 states, "a consented power station's CCR assessments should be to let Government know whether circumstances have changed such that there is any technical reason why an applicant's original proposals cannot now be implemented". As part of this it is generally necessary to review this storage capacity and availability periodically. However, the Applicant is proposing to seek CO_2 storage capacity via the Track 1 expansion process and, if successful, would become part of the HyNet CCS network. On this basis, any ongoing review is not deemed to be necessary.

8. Health and Safety Assessment

8.1 Overview

8.1.1 The primary aspects relating to health and safety arising from the operation of a carbon capture plant are on site aspects such as chemicals handling and, largely, off site aspects related to the transport of CO_2.

8.2 On-site aspects

8.2.1 The hazards associated with MEA are well understood. It is anticipated that the material would be brought on-site in concentrated form and diluted with water for direct use in the carbon capture process. MEA is not considered a dangerous substance, as classified under Control of Major Accident Hazards (COMAH) Regulations 2015, and would not activate the need for a Hazardous Substances Consent, in isolation.

8.2.2 Other smaller volumes of material will be required to serve the carbon capture plant, including sources of alkaline for solvent management and flue gas cleaning, hydrogen for CO_2 conditioning and acids for flue gas polishing.

8.2.3 There will be no bulk storage of CO_2 on site , and the only CO_2 stored on site will be the inventory in piping moving CO_2 off site.

8.2.4 Nevertheless, it is the case that the Proposed Development could require a Hazardous Substances Consent, and COMAH licensing when the complete inventory of substances on site is considered. This will then trigger additional health and safety management requirements, over and above those already in place at the site and subject to oversight by NRW and HSE.

8.2.5 As the design of the Proposed Development progresses, health and safety considerations will be taken into account and any identified risks mitigated (by design and management) to levels demonstrably considered to represent ALARP (As Low As Reasonably Practicable).

8.3 Off-site aspects

8.3.1 CO_2 captured will be retained in the gaseous phase, rather than compressed to being a supercritical fluid. Currently, CO_2 at high pressure (in any phase) is not listed as a Hazardous Substance by HSE, a 'dangerous substance' under COMAH, or as a dangerous fluid under the Pipelines Safety Regulations 1996 (PSR). However, guidance on CO_2 safety from the Health and Safety Executive (Ref 8) is that it should be considered as hazardous, and there is the potential for CO_2 in the supercritical, or gaseous, phase to be termed hazardous in the future. Whilst not to be under-estimated, the hazards associated with the repurposing of the pipeline in the CO_2 connection corridor are deemed lower than would be the case for CO_2 transported at higher pressure due to the relatively short distance being considered, and the fact the pipeline (for the most part) already exists and its integrity is understood.

9. Economic Appraisal

9.1.0 The Carbon Capture Readiness Guidelines require that the economics of schemes are considered to be feasible. The details of demonstrating this feasibility are left to the developer's discretion but typically, this would involve taking into account various scenarios involving assumptions such as infrastructure usage, shared facilities, future carbon prices etc. and comparing CCS operational cases with business as usual cases.

9.1.1 However. In applying for a DCO to carry out the Proposed Development, Uniper is seeking to invest in low carbon flexible power generation to support the national grid, and furthermore in the footprint, connections and associated powers to fit carbon capture and export the captured CO2 via a short connecting pipeline to the HyNet CO2 pipeline for offshore storage. The Proposed Development is supported by UK Government (Ref 5), as is the further deployment of carbon capture technology (Ref 6).

9.1.2 The means to unlock investment in the Proposed Development is the Dispatchable Power Agreement (DPA). The first such DPA contract has been awarded to the Net Zero Teesside project (Ref 7). The intention of the DPA is, as has been the case for Contracts for Difference in the renewables sector, to bridge the financial gap for power CCS projects, by allowing invested capital to be paid back to the developer (subject to meeting the contractual requirements of the counterparty). Furthermore, the DPA incentivises plant to operate in the energy market as the first plant in the merit order after renewables and other zero carbon generation types. Therefore, supporting the deployment of other low carbon technologies.

9.1.3 Therefore, subject to being awarded a DPA to support low carbon flexible power generation, there is clearly an economic case for carbon capture at the Proposed Development.

10. CCR Review

10.1.0 As the Proposed Development is intended to be equipped with carbon capture technology from the outset and, subject to being granted consent, will be built utilising the HyNet CO2 transport and storage infrastructure, the need for ongoing reviews of carbon capture readiness is considered to be unnecessary.

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