The Keadby 3 Low Carbon Gas Power Station Project

Document Ref: 5.8

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The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

Land at and in the vicinity of the Keadby Power Station site, Trentside, Keadby, North Lincolnshire

Carbon Capture Statement

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 – Regulation 5(2)(q)

Applicant: Keadby Generation Limited

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GLOSSARY

Abbreviation	Description
ACoP	Approved Code of Practice - laid down by the CDM Regulations 2015.
AGI	Above Ground Installation - installations used to support the safe and efficient operation of a pipeline; above ground installations are needed at the start and end of a cross-country pipeline and at intervals along the route.
ALARP	As Low As Reasonably Practicable – the level to which the risk is expected to be controlled.
BEIS	Department for Business, Energy and Industrial Strategy – department of the UK Government.
CCGT	Combined Cycle Gas Turbine - a highly efficient form of energy generation technology. An assembly of heat engines work in tandem using the same source of heat to convert it into mechanical energy which drives electrical generators and consequently generates electricity.
CCP	Carbon Capture Plant - plant used to capture carbon dioxide (CO_2) emissions produced from the use of fossil fuels in electricity generation and industrial processes.
CCR	Carbon Capture Readiness - space to be set aside to accommodate future carbon capture equipment.
CCS	Carbon Capture and Storage - see CCUS below.
CCUS	Carbon Capture, Usage and Storage - group of technologies designed to reduce the amount of carbon dioxide released into the atmosphere from coal and gas power stations as well as heavy industry including cement and steel production. Once captured, the carbon dioxide can be either re-used in various products, such as cement or plastics (usage) or stored in geological formations deep underground (storage).
CDM	Construction Design and Management Regulations 2015 - legal duties for safe operation of UK construction sites, including health and safety plans.

Abbreviation	Description
COMAH	Control of Major Accident Hazards Regulations 2015 - Regulations to ensure that businesses take all necessary measures to prevent major accidents involving dangerous substances.
DCF	Discounted Cash Flow - a method of estimating what an asset is worth today.
DCO	Development Consent Order - made by the relevant Secretary of State pursuant to The Planning Act 2008 to authorise a Nationally Significant Infrastructure Project. A DCO can incorporate or remove the need for a range of consents which would otherwise be required for a development. A DCO can also include rights of compulsory acquisition.
DECC	Department of Energy and Climate Change
EPS	Emissions Performance Standard - emissions standards set by the UK Government.
ES	Environmental Statement - a report in which the process and results of an Environment Impact Assessment are documented.
ETS	Emissions Trading Scheme – the UK ETS was established by the UK Government to increase the climate ambition of the UK's carbon pricing policy and to replace the UK's participation in the EU ETS.
EU	European Union - a political and economic union of 27 member states.
FEED	Front End Engineering Design - engineering which comes after the conceptual design (Pre-FEED) or feasibility study focusing on the technical requirements and estimated investment cost for the project.
GGH	Gas to Gas Heat Exchanger - transfer of heat from one process gas to another gas.
HSE	Health and Safety Executive - the body responsible for the encouragement, regulation and enforcement of workplace health, safety and welfare.
IED	The Industrial Emissions Directive (Directive 2010/75/EU) - European Union Directive committing member states to control and reduce the impact of industrial emissions on the environment.
LCOE	Levelised Cost of Electricity – used to compare and value energy production methods.
LCP	Large Combustion Plant - a combustion plant with a thermal capacity of 50 MW or greater.
MAHP	Major Accident Hazard Pipeline - these include high pressure natural gas supply transmission and distribution network. They

Abbreviation	Description
	also cover other pipeline systems transporting oils, chemicals and other gases.
MAPP	Major Accident Hazard Prevention Policy - sets out the major accident prevention policy.
MW; MWe	Megawatt - unit of energy; MWe megawatt electrical generation output
NEP	The Northern Endurance Partnership - a partnership between bp, Eni, Equinor, National Grid, Shell and Total to develop infrastructure to transport and store carbon dioxide emissions.
NLC	North Lincolnshire Council
NPS	National Policy Statement - Statement produced by Government under the Planning Act 2008 providing the policy framework for Nationally Significant Infrastructure Projects. They include the Government's view of the need for and objectives for the development of Nationally Significant Infrastructure Projects in a particular sector such as energy and are used to determine applications for such development.
NSIP	Nationally Significant Infrastructure Project - defined by the Planning Act 2008 and cover projects relating to energy (including generating stations, electric lines and pipelines); transport (including trunk roads and motorways, airports, harbour facilities, railways and rail freight interchanges); water (dams and reservoirs, and the transfer of water resources); waste water treatment plants and hazardous waste facilities. These projects are only defined as nationally significant if they satisfy a statutory threshold in terms of their scale or effect.
PPE	Personal Protective Equipment - equipment that will protect the user against health or safety risks at work.
SNS	Southern North Sea Basin – subsection of the North Sea Basin.
SoS	Secretary of State - title typically held by Cabinet Ministers in charge of Government Departments.
ZCH	Zero Carbon Humber – Separately consented carbon dioxide gathering network including a carbon dioxide export pipeline, to be designed and operated by third party.

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EXECUTIVE SUMMARY

1 Keadby Generation Limited (the 'Applicant') is seeking development consent for the construction, operation and maintenance of a new low carbon Combined Cycle Gas Turbine (CCGT) Generating Station ('the Proposed Development'). The Proposed Development is a new gas fired electricity generating station of up to 910 megawatts (MW) of gross electrical output with state-of-the art carbon capture technology and including cooling water, electrical, gas and utility connections, construction laydown areas and other associated works (the Proposed Development) on land to the west of the existing Keadby 2 Power Station, under construction. The Proposed Development will therefore make a significant contribution toward the UK reaching its Net Zero greenhouse gas emissions target by 2050.

2 The purpose of this document is to demonstrate that it is technically feasible to incorporate Carbon Capture technology within the Proposed Development and therefore that it is Carbon Capture Ready in accordance with the Carbon Capture Readiness (CCR) (Electricity Generating Stations) Regulations 2013 and Section 4.7 of the 'Overarching National Policy Statement for Energy' and Chapter 3 of Part 1 of the Energy Act 2008.

3 This document has been produced in accordance with the requirements of 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.'

4 Following a technical feasibility assessment of the proposed Carbon Capture and Storage (CCS) technology, the likely sizing and utility demand has been established. The site layout for the Proposed Development shows that there is sufficient space for the CCS technology within the Proposed Development Site based on this assessment.

5 The Proposed Development Site has been sited to connect into the carbon dioxide gathering network including an export pipeline that will be designed and operated by other parties in the Zero Carbon Humber (ZCH) Partnership. The carbon dioxide storage location currently proposed by the ZCH Partnership is the Endurance saline aquifer within the North Sea, with a storage capacity capable of accepting the carbon output from the Proposed Development and other regional emitters over its design life. It is intended that the carbon dioxide captured from the Proposed Development will be transported to the offshore storage site via pipeline, for which onshore proposals and a DCO application are being developed by the National Grid Carbon (NCG), and offshore pipeline proposals are being progressed by Northern Endurance Partnership (NEP).

6 In applying for a DCO for the Proposed Development, the Applicant has invested in de-risking the deployment of CCS technology through the dedication of space and through seeking powers for its development. The Applicant is proposing to further invest in the construction, operation and maintenance of Carbon Capture Plant (CCP), carbon dioxide compression facilities and

connection to third party carbon dioxide export and storage infrastructure. The economic viability of the CCP is contingent on the outcome of the selection process under the Government CCS Infrastructure Fund and negotiations under the Dispatchable Power Agreement, as well as the long-term carbon price.

7 It is likely that the onshore and offshore carbon dioxide transport from the Proposed Development Site will be in a 'dense phase' and that the pipeline would therefore be considered to be a Major Accident Hazard Pipeline (MAHP). It is considered that the risks of any dense phase carbon pipeline can be appropriately mitigated through the routing and design of the pipeline, and that potential significant effects of accident scenarios can be mitigated at the detailed design phase of the carbon dioxide transport network.

8 It is envisaged that the Proposed Development is likely to come under the Planning (Hazardous Substances) Regulations (as amended) 2015 consenting regime and may trigger the need for lower tier Control of Major Accident Hazard (COMAH) licensing under the COMAH Regulations 2015. This will be determined at the detailed design stage.

9 In conclusion, the Proposed Development demonstrates and commits to including a CCP integrated to a gas-fired power generation plant in one facility from the outset and is therefore CCR compliant. In addition, the Proposed Development compliments renewable energy by being dispatchable and helps to decarbonise the electricity grid when operating by reducing the need for unabated power supplies.

1.0 INTRODUCTION

1.1 Overview

1.1.1 This Carbon Capture Readiness ('CCR') Assessment (**Application Document Ref. 5.8**) has been prepared by AECOM on behalf of Keadby Generation Ltd (the 'Applicant') which is a wholly owned subsidiary of SSE plc. It forms part of the application (the 'Application') for a Development Consent Order (a 'DCO'), that has been submitted to the Secretary of State (the 'SoS') for Business, Energy and Industrial Strategy, under section 37 of 'The Planning Act 2008' (the '2008 Act').

1.1.2 The Applicant is seeking development consent for the construction, operation and maintenance of a new low carbon Combined Cycle Gas Turbine (CCGT) Generating Station ('the Proposed Development') on land at, and in the vicinity of, the existing Keadby Power Station, Trentside, Keadby, Scunthorpe DN17 3EF (the 'Proposed Development Site').

1.1.3 The Proposed Development is a new electricity generating station of up to 910 megawatts (MW) gross electrical output, equipped with carbon capture and compression plant and fuelled by natural gas, on land to the west of Keadby 1 Power Station and the (under construction) Keadby 2 Power Station, including connections for cooling water, electrical, gas and utilities, construction laydown areas and other associated development. It is described in **Chapter 4:** The Proposed Development of the Environmental Statement (ES) (ES Volume I - **Application Document Ref. 6.2**).

1.1.4 The Proposed Development falls within the definition of a 'Nationally Significant Infrastructure Project' (NSIP) under Section 14(1)(a) and Sections 15(1) and (2) of the 2008 Act, as it is an onshore generating station in England that would have a generating capacity greater than 50 MW electrical output (50 MWe). As such, a DCO application is required to authorise the Proposed Development in accordance with Section 31 of the 2008 Act.

1.1.5 The DCO, if made by the SoS, would be known as 'The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order' (the Order).

1.2 The Applicant

1.2.1 The Applicant, Keadby Generation Limited, is the freehold owner of a large part of the Proposed Development Site and is a wholly owned subsidiary of the FTSE 100-listed SSE plc, one of the UK's largest and broadest-based energy companies, and the country's leading developer of renewable energy generation. Over the last 20 years, SSE plc has invested over £20bn to deliver industry-leading offshore wind, onshore wind, CCGT, energy from waste, biomass, energy networks and gas storage projects. The Applicant owns and operates the adjacent Keadby 1 Power Station and is in the process of constructing Keadby 2 Power Station. SSE operates the Keadby Windfarm which lies to the north and south of the Proposed Development Site and

generates renewable energy from 34 turbines, with a total installed generation capacity of 68MW.

1.2.2 SSE has produced a 'Greenprint' document (SSE plc, 2020a) that sets out a clear commitment to investment in low carbon power infrastructure, working with government and other stakeholders to create a net zero power system by 2040. This includes investment in flexible sources of electricity generation and storage for times of low renewable output which will complement other renewable generating sources, using low carbon fuels and/ or capturing and storing carbon emissions. SSE is working with leading organisations across the UK to accelerate the development of carbon capture, usage and storage ('CCUS') clusters, including Equinor and National Grid Carbon (NGC).

1.2.3 The design of the Proposed Development demonstrates this commitment. The Proposed Development will be built with a clear route to decarbonisation, being equipped with post-combustion carbon capture technology, consistent with SSE's commitment to reduce the carbon intensity of electricity generated by 60% by 2030, compared to 2018 levels (SSE plc, 2020b). It is intended that the Proposed Development will connect to infrastructure that will be delivered by the Zero Carbon Humber (ZCH) Partnership[1] and Northern Endurance Partnership (NEP)[2] for the transport and offshore geological storage of carbon dioxide.

1.3 What is Carbon Capture, Usage and Storage?

1.3.1 CCUS is a process that removes carbon dioxide emissions at source, for example emissions from a power station or industrial installation, and then compresses the carbon dioxide so that it can be safely transported to secure underground geological storage sites. It is then injected into layers of solid rock filled with interconnected pores where the carbon dioxide becomes trapped and locked in place, preventing it from being released into the atmosphere. Plate 1 shows what is involved in the process.

[1] https://www.zerocarbonhumber.co.uk/the-vision/

[2] https://www.zerocarbonhumber.co.uk/news/northern-endurance-partnership/

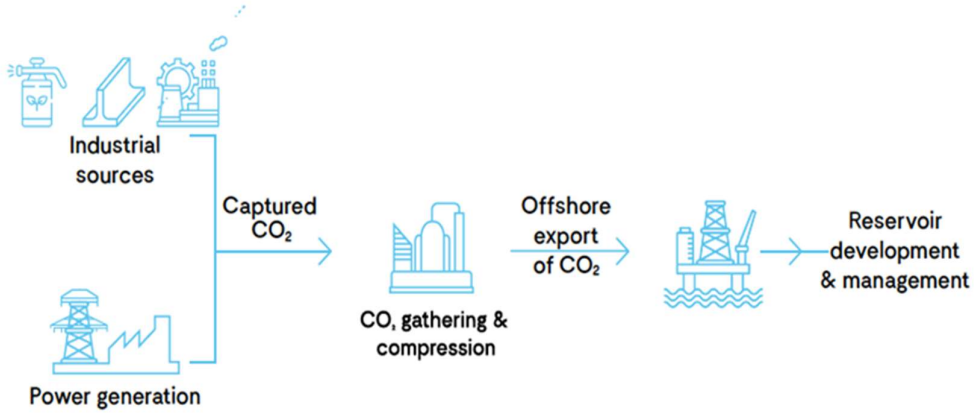


Plate 1: Illustration of the Carbon Capture, Usage and Storage

1.3.2 The technologies used in CCUS are proven and have been used safely across the world for many years. Geological storage sites are located far underground and are subject to stringent tests to ensure that they are geologically suitable. It is expected that the storage sites will be located offshore, in areas such as the North Sea. The NEP has been formed to develop the offshore infrastructure to transport and store carbon dioxide emissions in the North Sea.

1.3.3 CCUS is crucial to reducing carbon dioxide emissions and combatting global warming. The UK Government has committed to achieving Net Zero in terms of greenhouse gas emissions by 2050. This is a legally binding target. UK Government policy further states that the '*deployment of power CCUS projects will play a key role in the decarbonisation of the electricity system at low cost'* (HM Government, 2020a, page 47).

1.3.4 The Proposed Development will provide up to 910 MWe (gross) of dispatchable capacity and capture some 2 million tonnes of carbon dioxide per annum, dependent upon the turbine equipment chosen and the running hours of the plant. The Proposed Development could be up and running by the mid-2020s and will facilitate the timely development of a major CCUS cluster in the Humber region, making an important contribution towards the achievement of Net Zero by 2050.

1.4 The Proposed Development

1.4.1 The Proposed Development will work by capturing carbon dioxide emissions from the gas-fired power station and connecting into the ZCH Partnership export pipeline and gathering network for onward transport to the Endurance saline aquifer under the North Sea.

1.4.2 The Proposed Development would comprise a low carbon gas fired power station with a gross electrical output capacity of up to 910 MWe and associated buildings, structures and plant and other associated development defined in the

Schedule 1 of the draft DCO (**Application Document Ref. 2.1**) as Work No. 1 – 11 and shown on the Works Plans (**Application Document Ref. 4.3**).

1.4.3 At this stage, the final technology selection cannot yet be made as it will be determined by various technical and economic considerations and will be influenced by future UK Government policy and regulation. The design of the Proposed Development therefore incorporates a necessary degree of flexibility to allow for the future selection of the preferred technology in the light of prevailing policy, regulatory and market conditions once a DCO is made.

1.4.4 The Proposed Development will include:

- a carbon capture equipped electricity generating station including a CCGT plant (**Work No. 1A**) with integrated cooling infrastructure (**Work No. 1B**), and carbon dioxide capture plant (CCP) including conditioning and compression equipment, carbon dioxide absorption unit(s) and stack(s) (**Work No. 1C**), natural gas receiving facility (**Work No. 1D**), supporting uses including control room, workshops, stores, raw and demineralised water tanks and permanent laydown area (**Work No. 1E**), and associated utilities, various pipework, water treatment plant, wastewater treatment, firefighting equipment, emergency diesel generator, gatehouse, chemical storage facilities, other minor infrastructure and auxiliaries/ services (all located in the area referred to as the 'Proposed Power and Carbon Capture (PCC) Site' and which together form **Work No. 1**);
- natural gas pipeline from the existing National Grid Gas high pressure (HP) gas pipeline within the Proposed Development Site to supply the Proposed PCC Site including an above ground installation (AGI) for National Grid Gas's apparatus (**Work No. 2A**) and the Applicant's apparatus (**Work No. 2B**) (the 'Gas Connection Corridor');
- electrical connection works to and from the existing National Grid 400 kV Substation for the export of electricity (**Work No. 3A**) (the 'Electrical Connection Area to National Grid 400 kV Substation');
- electrical connection works to and from the existing Northern Powergrid 132 kV Substation for the supply of electricity at up to 132 kV to the Proposed PCC Site, and associated plant and equipment (**Work No. 3B**) (the 'Potential Electrical Connection to Northern Powergrid 132 kV Substation');
- Water Connection Corridors to provide cooling and make-up water including:
  - underground and/ or overground water supply pipeline(s) and intake structures within the Stainforth and Keadby Canal, including temporary cofferdam (**Work No. 4A**) (the 'Canal Water Abstraction Option');
  - in the event that the canal abstraction option is not available, works to the existing Keadby 1 power station cooling water supply pipelines and intake structures within the River Trent, including temporary cofferdam (**Work No. 4B**) (the 'River Water Abstraction Option');

  - works to and use of an existing outfall and associated pipework for the discharge of return cooling water and treated wastewater to the River Trent (**Work No. 5**) (the 'Water Discharge Corridor');

- towns water connection pipeline from existing water supply within the Keadby Power Station to provide potable water (**Work No. 6**);
- above ground carbon dioxide compression and export infrastructure comprising an above ground installation (AGI) for the undertaker's apparatus including deoxygenation, dehydration, staged compression facilities, outlet metering, and electrical connection (**Work No. 7A**) and an above ground installation (AGI) for NGC's apparatus (**Work No. 7B**);
- new permanent access from A18, comprising the maintenance and improvement of an existing private access road from the junction with the A18 including the western private bridge crossing of the Hatfield Waste Drain (**Work No. 8A**) and installation of a layby and gatehouse (**Work No. 8B**), and an emergency vehicle and pedestrian access road comprising the maintenance and improvement of an existing private track running between the Proposed PCC Site and Chapel Lane, Keadby and including new private bridge (**Work No. 8C**);
- temporary construction and laydown areas including contractor facilities and parking (**Work No. 9A**), and access to these using the existing private roads from the A18 and the existing private bridge crossings, including the replacement of the western existing private bridge crossing known as 'Mabey Bridge') over Hatfield Waste Drain (**Work No. 9B**) and a temporary construction laydown area associated with that bridge replacement (**Work No. 9C**);
- temporary retention, improvement and subsequent removal of an existing Additional Abnormal Indivisible Load Haulage Route (**Work No. 10A**) and temporary use, maintenance, and placement of mobile crane(s) at the existing Railway Wharf jetty for a Waterborne Transport Offloading Area (**Work No. 10B**);
- landscaping and biodiversity enhancement measures (**Work No. 11A**) and security fencing and boundary treatments (**Work No. 11B**); and
- associated development including: surface water drainage systems; pipeline and cable connections between parts of the Proposed Development Site; hard standings and hard landscaping; soft landscaping, including bunds and embankments; external lighting, including lighting columns; gatehouses and weighbridges; closed circuit television cameras and columns and other security measures; site preparation works including clearance, demolition, earthworks, works to protect buildings and land, and utility connections; accesses, roads, roadways and vehicle and cycle parking; pedestrian and cycle routes; and temporary works associated with the maintenance of the authorised development.

1.4.5 The Applicant will be responsible for the construction, operation (including maintenance) and eventual decommissioning of the Proposed Development, with the exception of the National Grid Gas compound works (**Work No. 2A**), the works within the National Grid Electricity Transmission 400 kV substation (part of **Work No. 3A**), the works within the Northern Powergrid 132 kV substation (part of **Work No. 3B**), and the NGC compound works (**Work No. 7B**), which will be the responsibility of those named beneficiaries.

1.4.6 The Proposed Development includes the equipment required for the capture and compression of carbon dioxide emissions from the generating station so that it is capable of being transported off-site. ZCH Partnership will be responsible for the construction, operation and decommissioning of the carbon dioxide gathering network linking onshore power and industrial facilities including the Proposed Development in the Humber Region. The carbon dioxide export pipeline does not, therefore, form part of the Proposed Development and is not included in the Application but will be the subject of separate consent applications by third parties, such as the Humber Low Carbon Pipeline DCO Project by NGC[3].

1.4.7 The Proposed Development will be designed to operate 24 hours per day, 7 days per week with programmed offline periods for maintenance. It is anticipated that in the event of CCP maintenance outages, for example, it will be necessary to operate the Proposed Development without carbon capture, with exhaust gases from the CCGT being routed via the Heat Recovery Steam Generator (HRSG) stack. After a period of baseload operation, there is the opportunity for the Proposed Development to operate in dispatchable model, i.e. being able to export power into the day-ahead market to match the anticipated intermittency of renewable power in the future market.

1.4.8 Various types of associated and ancillary development further required in connection with and subsidiary to the above works are detailed in Schedule 1 'Authorised Development' of the draft DCO (**Application Document Ref. 2.1**). This along with **Chapter 4:** The Proposed Development in the ES Volume I (**Application Document Ref. 6.2**) provides further description of the Proposed Development. The areas within which each numbered Work (component) of the Proposed Development are to be built are defined by the coloured and hatched areas on the Works Plans (**Application Document Ref. 4.3**).

1.5 The Proposed Development Site

1.5.1 The Proposed Development Site (the 'Order Limits') is located within and near to the existing Keadby Power Station site near Scunthorpe, Lincolnshire and lies within the administrative boundary of North Lincolnshire Council (NLC). The majority of land is within the ownership or control of the Applicant (or SSE

[3] https://infrastructure.planninginspectorate.gov.uk/projects/yorkshire-and-the-humber/humber-low-carbon-pipelines/

associated companies) and is centred on national grid reference 482351, 411796.

1.5.2 The existing Keadby Power Station site currently encompasses the operational Keadby 1 and (under construction) Keadby 2 Power Station sites, including the Keadby 2 Power Station Carbon Capture and Readiness reserve space.

1.5.3 The Proposed Development Site encompasses an area of approximately 69.4 hectares (ha). This includes an area of approximately 18.7 ha to the west of Keadby 2 Power Station in which the generating station (CCGT plant, cooling infrastructure and CCP) and gas connection will be developed (the Proposed PCC Site).

1.5.4 The Proposed Development Site includes other areas including:

- Previously developed land, along with gas, towns water and other connections, and access routes, within the Keadby Power Station site;
- the National Grid 400 kV Substation located directly adjacent to the Proposed PCC Site, through which electricity generated by the Proposed Development will be exported;
- Emergency Vehicle Access Road and Potential Electrical Connection to Northern Powergrid Substation, the routes of which utilise an existing farm access track towards Chapel Lane and land within the existing Northern Powergrid substation on Chapel Lane;
- Water Connection Corridors:
  - Canal Water Abstraction Option which includes land within the existing Keadby Power Station site with an intake adjacent to the Keadby 2 Power Station intake and pumping station and interconnecting pipework;
  - River Water Abstraction Option which includes a corridor that spans Trent Road and encompasses the existing Keadby Power Station pumping station, below ground cooling water pipework, and infrastructure within the River Trent; and
  - a Water Discharge Corridor which includes an existing discharge pipeline and outfall to the River Trent and follows a route of an existing easement for Keadby 1 Power Station;
- an existing river wharf at Railway Wharf (the Waterborne Transport Offloading Area) and existing temporary haul road into the into the existing Keadby 1 Power Station Site (the 'Additional Abnormal Indivisible Load (AIL) Route');
- a number of temporary Construction Laydown Areas on previously developed land and adjoining agricultural land; and
- land at the A18 Junction and an existing site access road, including two existing private bridge crossing of the Hatfield Waste Drain lying west of Pilfrey Farm (the western of which is known as Mabey Bridge, to be

replaced, and the eastern of which is termed Skew Bridge) and an existing temporary gatehouse, to be replaced in permanent form.

1.5.5 In the vicinity of the Proposed Development Site the River Trent is tidal, therefore parts of the Proposed Development Site are within the UK marine area. No harbour works are proposed.

1.5.6 Further description of the Proposed Development Site and its surroundings is provided in **Chapter 3:** The Site and Surrounding Area in ES Volume I (**Application Document Ref. 6.2**).

1.6 The Development Consent Process

1.6.1 As a NSIP project, the Applicant is required to obtain a DCO to construct, operate and maintain the generating station, under Section 31 of the 2008 Act. Sections 42 to 48 of the 2008 Act govern the consultation that the promoter must carry out before submitting an application for a DCO and Section 37 of the 2008 Act governs the form, content and accompanying documents that are required as part of a DCO application. These requirements are implemented through the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended) ('APFP Regulations') which state that an application must be accompanied by an ES, where a development is considered to be 'EIA development' under the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations).

1.6.2 An application for development consent for the Proposed Development has been submitted to the Planning Inspectorate (PINS) acting on behalf of the Secretary of State. Subject to the Application being accepted (which will be decided within a period of 28 days following receipt of the Application), PINS will then examine it and make a recommendation to the Secretary of State, who will then decide whether to make (grant) the DCO.

1.7 The Purpose and Structure of this Document

1.7.1 The purpose of this document is to comply with Section 4.7.10 of the 'Overarching National Policy Statement for Energy (EN-1)', which requires developers promoting thermal generating stations to demonstrate CCR.

1.7.2 As the output capacity of the Proposed Development is greater than 300 MWe, the generating station falls under the provisions of the Carbon Capture Readiness (Electricity Generating Stations) Regulations 2013 (the 'CCR Regulations') (HMSO, 2013), which transposed Article 36 of Directive on Industrial Emissions (Integrated Pollution Prevention and Control) (Directive 2010/75/EU) ('the Industrial Emissions Directive' (IED)) into UK legislation.

1.7.3 The CCR Regulations provide that no DCO (in England and Wales) may be made in relation to a combustion plant with a capacity at or over 300 MWe, unless the relevant authority has determined (on the basis of an assessment carried out by an applicant) whether it is technically and economically feasible

to retrofit the equipment necessary to capture the carbon dioxide that would otherwise be emitted from the plant, and to transport and store such carbon dioxide from the site.

1.7.4 The Applicant must therefore demonstrate that the CCGT Generating Station is CCR under the regulatory requirements for an application for DCO.

1.7.5 The Proposed Development has been specifically designed, at the outset, to include the construction, operation and maintenance of a post-combustion CCP, carbon dioxide compression facilities and connection to third party carbon dioxide export and transportation infrastructure.

1.7.6 This CCR assessment has therefore been prepared in accordance with the Department of Energy and Climate Change (DECC) 2009 CCR Guidance (see Section 2.3) to confirm that the specific requirements under the CCR Regulations have been met, noting that the basis of CCR demonstration is for retrofit to a generating station whereas the Proposed Development includes carbon capture within the CCGT Pre-FEED design and therefore the assessment has interpreted the CCR Guidance to account for this. The document also outlines the responsibilities and consenting route for the anticipated third party gathering network.

1.7.7 This report provides the Applicant's evidence submitted in demonstration of CCR, and is structured as follows:

- Section 2 outlines policy context relating to CCR, summarises the guidance on the information required as part of a DCO application to demonstrate CCR, and describes the assessment methodology used;
- Section 3 provides a description of the Proposed Development and outlines the responsibilities and consenting status of the anticipated third party gathering network;
- Section 4 outlines the technical assessment of CCUS;
- Section 5 outlines the economic assessment of CCUS;
- Section 6 outlines the health and safety considerations for the proposed CCP; and
- Section 7 presents the conclusions of this CCR assessment.

2.0 POLICY CONTEXT AND ASSESSMENT METHODOLOGY

2.1 Carbon Capture Readiness (Electricity Generating Stations) Regulations 2013

2.1.1 The CCR Regulations came into force on 25 November 2013. These regulations were made in transposition of Article 36 of the EU Industrial Emissions Directive (see box below).

EU DIRECTIVES

Some types of EU legislation, such as Directives, are indirectly applicable, meaning domestic legislation is required by EU member states to become law. In the UK this was often achieved via Statutory Instruments rather than passing primary legislation. The UK government has made the EU Withdrawal Act 2018 which maintains established environmental principles and ensures that existing EU environmental law will continue to have effect in UK law.

The European Union (EU) published the Directive on the Geological Storage of Carbon Dioxide (Directive 2009/31/EC) ("the Directive") in the Official Journal of the European Union on 5 June 2009, with the Directive coming into force on 25 June 2009.

Article 21 of the Directive requires that necessary measures are taken to allow access to transport networks and storage sites for geological storage of produced and captured CO_2.

Article 33 of the Directive requires an amendment to Directive 2001/80/EC (commonly known as the Large Combustion Plants Directive ("LCP")), via Article 9a, such that operators of all combustion plants with an electrical output of 300 MW or more (and for which the construction / operating license was granted after the date of the Directive) are required to carry out a study to assess:

- Whether suitable storage sites for carbon dioxide are available;
- Whether transport facilities to transport carbon dioxide are technically and economically feasible; and
- Whether it is technically and economically feasible to retrofit for the capture of carbon dioxide emitted from the power station;
- This may be known as a 'CCR Feasibility Study', to be determined by the competent authority.

The Industrial Emissions Directive ("IED", Directive 2010/75/EU) entered into force in January 2011 and was to be transposed into national legislation by Member States by January 2013. The IED brought together seven existing directives, including the LCP. Article 36 of the IED replicates the requirements of Article 9a of Directive 2001/80/EC (LCP) and the above requirement for a CCR Feasibility Study.

2.1.2 The CCR Regulations provide that no order for development consent (in England and Wales) may be made in relation to a combustion plant with a capacity at or over 300 MWe unless the relevant authority has determined (on the basis of an assessment carried out by the applicant) whether it is technically and economically feasible to retrofit the equipment necessary to capture the carbon dioxide that would otherwise be emitted from the plant, and to transport such carbon dioxide from the site to an appropriate long term geological store.

2.1.3 The CCR Regulations summarise the need for a CCR Feasibility Study and state (at Regulation 2(1)) that a: *'CCR Assessment, in relation to a combustion plant, means an assessment as to whether the CCR Conditions are met in relation to that plant.*' In terms of the 'CCR Conditions', CCR Regulation 2(2) states that:

'for the purposes of these Regulations, the CCR Conditions are met in relation to a combustion plant, if, in respect of all of its expected emissions of CO_2 –

a) suitable storage sites are available;

b) it is technically and economically feasible to retrofit the plant with the equipment necessary to capture that CO_2; and

c) it is technically and economically feasible to transport such captured CO_2 to the storage sites'.

2.1.4 Furthermore, CCR Regulation 3(1) states that:

"The Secretary of State must not make a relevant consent order unless the Secretary of State has determined whether the CCR Conditions are met in relation to the combustion plant to which the consent order relates".

2.1.5 CCR Regulation 3(3) states that:

"If the Secretary of State –

a) determines that the CCR Conditions are met in relation to a combustion plant; and

b) decides to make a relevant consent order in respect of that plant,

the Secretary of State must include a requirement in the relevant consent order that suitable space is set aside for the equipment necessary to capture and compress all of the CO_2 that would otherwise be emitted from the plant."

2.2 National Policy Statements

2.2.1 The National Policy Statements (NPS) for energy infrastructure form the policy framework for applications for new generating stations of greater than 50 MW capacity in England and Wales. The NPS of most relevance to the Proposed Development (and this CCR Assessment) are the 'Overarching National Policy

Statement on Energy (EN-1)' (DECC, 2011a) and the 'National Policy Statement for Fossil Fuel Electricity Generating Infrastructure (EN-2)' (DECC, 2011b).

2.2.2 Under Section 104(3) of the Planning Act 2008, DCO applications for NSIP are required to be determined by the SoS in accordance with policy set out in the relevant NPS. As stated in NPS EN-1:

"All applications for new combustion plant which are of generating capacity at or over 300MW and of a type covered by the EU's Large Combustion Plant Directive (LCPD) should demonstrate that the plant is 'Carbon Capture Ready' (CCR) before consent may be given. The [Secretary of State] *must not grant consent unless this is the case."*

2.2.3 In this regard, NPS EN-1 also states that:

"In order to assure the [Secretary of State] *that a proposed development is CCR, applicants will need to demonstrate that their proposal complies with guidance issued ... in November 2009 or any successor to it."*

2.2.4 The guidance referred to above is discussed in the Section 2.3 below.

2.2.5 NPS EN-2 (DECC, 2011b) reiterates the requirement for fossil fuel generating stations to be 'carbon capture ready'. The requirements set out in NPS EN-2 in relation to coal-fired generating stations have been applied to the proposed gas-fired generating station. NPS EN-2 states:

"The applicant should therefore provide evidence to show:

- *technically feasible plans for a CO_2 capture unit that meets the minimum size requirements;*
- *an Environmental Impact Assessment (EIA) that addresses impacts arising from the capture plant; and*
- *documentation to ensure compliance with all other existing policy including that any of the plant's capacity which is not to be fitted with CCS at the outset is carbon capture ready."*

2.2.6 NPS EN-2 states further:

"An application must contain sufficient information on the proposed plans for CCS to enable the IPC to determine whether the proposal meets the required criteria as set out in the draft DECC guidelines on CCS for developers. The IPC should also have regard to advice from the Environment Agency (EA) as to the technical feasibility of the proposed CCS. The IPC may also seek further independent advice but is not required to do so."

2.3 CCR Guidance

2.3.1 DECC published guidance on CCR in November 2009 entitled 'Carbon Capture Readiness (CCR) – A Guidance Note for Section 36 Electricity Act 1989 consent applications'. The guidance states that applicants are required to:

- demonstrate that sufficient space is available on or near the site to accommodate carbon capture equipment in the future;
- undertake an assessment into the technical feasibility of retrofitting CCP equipment;
- propose a suitable area of deep geological storage offshore for the storage of captured carbon dioxide;
- undertake an assessment into the technical feasibility of transporting the captured carbon dioxide to the proposed storage area;
- assess the likelihood that it will be economically feasible within the power station's lifetime to link it to a full CCUS chain, including retrofitting of capture equipment, transport and storage; and
- if necessary, apply for and obtain Hazardous Substance Consent (HSC) when applying for consent.

2.4 Assessment Methodology

2.4.1 This CCR report has therefore been prepared to fulfil the requirements of the DECC November 2009 guidance as set out below:

- Allocation of Space for CCP Equipment: An assessment of appropriate space set aside to accommodate future carbon capture equipment is provided in Section 4.1 of this report. The space allocated for the CCP has been calculated to demonstrate compliance with the minimum footprint in the guidance.
- Technical Assessment of Feasibility of CCP Retrofit: Annex C of the Guidance provides a detailed advisory checklist of the information to be included in a CCR Feasibility Study report on the technical assessment of the feasibility of retrofitting CCP equipment for a new natural gas combined cycle power station using post-combustion carbon capture. It is noted that a specific checklist for the technology intended for the Proposed Development is not provided by the guidance, however, for the purposes of this CCR Assessment, Section 4.2 of this report deals with the technical response to the requirements of Annex C, as being of most relevance to the Proposed Development.
- Technical Feasibility of Storage of Captured Carbon Dioxide: In accordance with the guidance, at least two fields or aquifers with an appropriate carbon dioxide storage capacity, which have been listed in either the 'valid' or 'realistic' categories in the 2006 study of UK Storage Capacity (BGS, 2006), (which is provided in Annex D of the CCR Guidance), should be proposed

as suitable carbon dioxide storage locations for the Proposed Development. Such sites are identified in Section 4.3 of this report.

- Technical Feasibility of Transport of Captured Carbon Dioxide: The Guidance states that the feasibility of any proposed site for a new combustion station will be influenced by the availability of transport routes to the proposed storage area. The technical feasibility of transporting the captured carbon dioxide to the storage area proposed for the Proposed Development is assessed in Section 4.4 of this report.
- Economic Assessment of the Feasibility of CCUS: The Guidance states that the main aim of the economic assessment is to provide an indication of the future likelihood of a retrofit of CCP equipment, carbon dioxide transport and storage of carbon dioxide being economically feasible at some stage during the proposed combustion plant's operational lifetime. This is developed in Section 5 of this report, recognising the position of the Proposed Development, which is to have CCUS from the outset (not retrofitted).
- Health and Safety Analysis: An analysis of health and safety issues associated with the CCP, including consideration of whether a Hazardous Substances Consent may be required for the Proposed Development, is provided in Section 6 of this report.

3.0 DESCRIPTION OF THE PROPOSED DEVELOPMENT

3.1 Location

3.1.1 The Proposed Development Site comprises land within and adjacent to the boundary of the existing Keadby Power Station site near Scunthorpe, Lincolnshire.

3.1.2 The Proposed Power and Carbon Capture (PCC) Site, on which the built development associated with the CCGT and CCP is proposed, is located approximately 4.1km to the west of the town of Scunthorpe.

3.2 Plant Description

3.2.1 This CCR study addresses the generating station and its readiness to address its own carbon dioxide emissions. The current CCR guidance (DECC, 2009) is based upon unabated plant capacity and therefore the largest gas turbine unit currently commercially available has been assumed as the basis for approximate values for the various plant requirements.

3.2.2 The generating station is likely to initially provide baseload electrical generation and assumed to operate for approximately 8,000 hours annually for the purposes of this CCR Assessment.

3.2.3 The Proposed Development will be designed to operate for up to 25 years, after which ongoing operation and market conditions will be reviewed. If it is not appropriate to continue operating after that time, the generating station will be decommissioned.

3.3 Carbon Capture and Storage Technology

3.3.1 The Proposed Development is to be one of the first projects to install and operate carbon capture technology on a gas-fired generating station. The current Emissions Performance Standard (EPS) set by the UK Government for new electricity generating stations is set at 450 gCO_2/kWh (Energy Act 2013, Part 2, Chapter 8). This EPS is proposed by UK Government to be maintained for consented plants until 2045.

3.3.2 There are three alternative carbon capture technologies available, namely:

- pre-combustion carbon capture;
- post-combustion carbon capture; and
- oxy-combustion carbon capture.

3.3.3 This CCR Assessment has focused on the use of post-combustion carbon capture, as this is the chosen technology included as part of the Proposed Development. No further discussion is presented in this report on the alternative technologies given that decision has been made.

3.3.4 The feasibility of CCUS for the Proposed Development has therefore been assessed on the basis of the best currently available post-combustion carbon capture technology which, for carbon capture from combustion flue gases, would use an amine-based solution as the absorption medium.

Process Design Basis

3.3.5 The conceptual design in this report has been based upon the post-combustion modelling developed using industry standard software and heat cycle data developed as part of the pre-FEED. In common with studies for other generating stations, a 90% carbon dioxide capture efficiency has been used as the basis for the design in this CCR report.

3.3.6 This Assessment has been developed for a single carbon capture train processing the mass flow rate of flue gas from the largest gas turbine unit currently commercially available.

3.3.7 The sizing and utility demand of the main CCP equipment required has been established using thermal and process modelling. The indicative site layout (**Application Document Ref. 4.7**, reproduced in Appendix A of this document) shows that the equipment fits within the land allocated for CCP (**Work No. 1C**).

3.4 Carbon Dioxide Gathering Network

3.4.1 ZCH Partnership is a consortium of energy and industrial companies, including the Applicant, with a shared plan to decarbonise industrial emissions. As part of the consortium, NGC is preparing a DCO application for the construction and operation of the 'Humber Low Carbon Pipeline' which once developed, would serve a number of key energy and industrial carbon dioxide producers, including the Proposed Development, prior to transition to offshore transport at Easington, north of the Humber Estuary for sequestration by the NEP within the Endurance saline aquifer.

3.4.2 It is recognised that the CCR Guidance states that an applicant may not assume, at the CCR stage, that they will be able to outsource onshore carbon dioxide transport and storage arrangements (such as to a cluster network). Whilst this is noted, the Applicant considers that the greater certainty over the ZCH Partnership cluster and in particular, the NGC Humber Low Carbon Pipeline DCO application, with intended links to the Proposed Development; the proposals for pipeline development by NEP to offshore geological store; and the commitment from Government to supporting the establishment of CCUS in four industrial clusters including the Humber Cluster (BEIS, Energy White Paper, December 2020) demonstrates that such links are justified within this Application. Indeed, the proposed ZCH Partnership is a key factor in the location of the Proposed Development.

3.4.3 NPS EN-2 states that any DCO (for coal-fired generating stations) should include the following pre-construction requirements, which are all reflected in

Schedule 2 of the draft DCO for the Proposed Development (**Application Document Ref. 2.1**) in an appropriate way and recognising that the Proposed Development is not for a coal-fired generating station.

3.4.4 The Applicant continues to engage with NGC regarding routing of the Humber Low Carbon Pipeline, taking into consideration technical and environmental opportunities and constraints.

4.0 TECHNICAL ASSESSMENT

4.1 Space

4.1.1 An indicative layout of the Proposed PCC Site, including the CCGT and CCP, has been developed as part of the initial engineering design work conducted.

4.1.2 The CCP incorporates all the major equipment items described in the following subsection (Section 4.2) with appropriate areas for ductwork, piping, access and maintenance available.

4.1.3 Appendix A shows the indicative plant layout for the CCP within the space allocated on site for CCR purposes.

Footprint Comparison

4.1.4 The 2009 CCR Guidance (DECC, 2009) provides an indicative CCR space requirement based on a 500 MW (net) power plant. For a CCGT power plant with post-combustion carbon capture, the indicative CCR space requirement was initially provided at 3.75 ha for 500 MW, which equates to 75 m^2/MW.

4.1.5 However, following the publication of the CCR Guidance, the indicative CCR space requirement was reviewed by Imperial College, London (Imperial College, 2010). The Imperial College review concluded that the footprint estimates presented in the 2009 CCR Guidance were overly conservative and recommended the reduction of the indicative CCR space requirement for a CCGT power plant with post-combustion capture by 36%. Therefore, the corrected indicative CCR space requirement is 2.4 ha for 500 MW. This equates to 48 m^2/MW.

4.1.6 In addition, the review by Imperial College further detailed additional scope for a reduction in the indicative CCR space requirement by 50% to 1.875 ha (including the reduction of 36%) considering technology advances and layout optimisation. This equates to 37.5 m^2/MW. However, the paper also states that such a reduction can only be justified following a detailed engineering design rather than only a linear scaling of this value.

4.1.7 At this consenting stage of the project, a number of the design aspects and features of the Proposed Development cannot be confirmed until the detailed design of the Proposed Development has been completed, therefore, for the purposes of this CCR Assessment, a 'worst-case' concept design and footprint area calculation has been estimated using the following sources of information:

- initial engineering studies developed as part of the Pre-FEED for the Proposed Development;
- DECC CCR Guidance (DECC, 2009); and
- Imperial College Paper on CCP Footprint Review (Imperial College, 2010).

4.1.8 On this basis, the indicative 'worst-case' total footprint has been estimated. A conservative design margin is applied to allow for ductwork, piping, access and maintenance, and to allow for the potential challenges of installing and maintaining a 'First of a Kind' plant (for which technology maturation and design optimisation may not be as advanced as for an 'Nth of a Kind' project).

4.1.9 AECOM has calculated an estimated carbon capture site area of circa 43,800 m^2 (4.38 ha) (50 m^2/MW) from the indicative CCP component design shown in **Error! Reference source not found.**. This figure is above the specific area target of 48 m^2/MW (without technology/ layout optimisation) and therefore indicates that the minimum required area has been allocated.

4.1.10 The land allocated for CCP is within the western part of the Proposed Development Site (**Work No. 1C** – **Application Document Ref. 4.3**) and is 6.55 ha in area, exceeding the 4.38 ha calculated to be required.

4.2 Indicative Process Description

Introduction

4.2.1 The Proposed Development has been assessed based on a nominal unabated capacity of 910 MWe for the proposed generating station, against the criteria presented in Annex C of the DECC CCR guidance note (DECC, 2009).

Design, Planning Permissions and Approvals

4.2.2 The feasibility of CCUS for the Proposed Development has been assessed on the basis of the best currently available technology, which for post-combustion carbon capture from flue gases, is capture using amine-based absorption. An outline level plot plant for the plant is provided in Appendix A.

Plant Location

4.2.3 It is anticipated that the exit point for the captured carbon dioxide from the Proposed Development will be located in the north part of the Proposed PCC Site. Discussions with ZCH Partnership are ongoing in respect of the required pipeline connections that form part of the Humber Low Carbon Pipeline DCO Application by NGC and the parties are working closely to identify options for pipeline routes, taking into consideration technical and environmental opportunities and constraints; but the exit point will remain within the relevant area (**Work No. 7** – **Application Document Ref. 4.3**), as shown in **Appendix A**.

4.2.4 Where appropriate, pipe racks will be used to transfer the compressed and dehydrated carbon dioxide to the defined exit point. This is achievable as the pipe will have a nominal bore of circa 260 mm assuming an allowable velocity of 2.0 m/s, due to the dense phase of the carbon dioxide.

4.2.5 Further information on the transport and storage of captured carbon dioxide off-site is provided in Sections 4.3 and 4.4.

Space Requirements

4.2.6 The footprint discussed in Section 4.1 above has been used to prepare the plot plan presented in Appendix A, which demonstrates that space has been allocated for the following:

- carbon dioxide capture equipment, including any flue gas pre-treatment, and carbon dioxide drying and compression;
- space for routing flue gas duct to the carbon dioxide capture equipment;
- any extensions or additions to the balance of plant on the gas turbine units where necessary to cater for the additional requirements of the capture equipment;
- maintenance and operational vehicle movement;
- space for storage and handling of amines and handling of carbon dioxide, including space for infrastructure to transport carbon dioxide to the plant boundary; and
- major plant deliveries and access around the Proposed PCC Site.

4.2.7 In terms of the land required for laydown during construction of the CCP, the areas are provided in **Work No. 9A** (**Application Document Ref. 4.3**) and shown on **Figure 5.1** (ES Volume III – **Application Document Ref. 6.4**). Areas required would be developed further in a detailed Construction Management Plan as part of the EPC Contractor's procurement and site management responsibility.

Gas Turbine Operation

4.2.8 The design for the CCP accounts for any backpressure in the flue gas flow path by inclusion of a booster fan/ blower to compensate for the pressure drop through the CCP (primarily in the absorbers, direct contact cooler and dampers) which is of the order of 140 mbar.

4.2.9 Based on the flue gas flow rate of around 1,000 kg/s with a nominal pressure rise of 140 mbar, a booster fan with a power rating of approximately 10.6 MWe has been included in the CCP power requirement.

Flue Gas System

4.2.10 The flue gas system has been developed based upon the concept and pre-FEED design of the CCGT post-combustion capture and includes similar design elements. The following flue gas system is proposed for the CCP.

Isolation and Bypass Dampers

4.2.11 The flue gas exiting the prime movers may be routed to a bypass or diverter damper (or other suitable technique), from where it may be directed either

directly to a stack (e.g. during start-up or fault conditions) but for normal operation through the CCP.

Flue Gas Cooling

4.2.12 The absorption process requires a flue gas cooler to lower the flue gas temperature to an acceptable temperature to enhance the carbon dioxide chemical absorption and to minimise amine degradation. The flue gas is routed to a direct contact cooler (DCC), which quenches the flue gas to an acceptable temperature for absorption. A small slipstream of the circulating cooling water is routed through the DCC water filter to remove particulate build-up. A portion of this particulate free stream is returned to the DCC; the other portion is directed to a wastewater treatment plant. Cool, saturated, flue gas from the DCC is extracted through the blower which is required to overcome the frictional losses in the ducting, gas-to-gas heat (GGH) exchangers, DCC and absorber.

4.2.13 A gas-to-gas Ljungström type heat exchanger, or alternative heat transfer technique, could be included prior to the DCC, if required. Heat would be transferred from the hot untreated flue gas stream to the cold treated purified flue gas stream. This heat exchanger would reduce the duty of DCC and would improve the dispersion of the treated flue gases into the atmosphere.

Carbon Dioxide Absorber

4.2.14 The cooled flue gas from the DCC is fed to the bottom of the counter current absorber where carbon dioxide in the flue gas is absorbed by the solvent. Flue gas enters near the bottom of the absorber and flows upward through packed beds. Carbon dioxide reacts chemically with the solvent and is absorbed into the bulk solution. Rich solvent leaves the bottom of the absorber and is transferred to the stripper by the rich solvent pump.

4.2.15 Stripped flue gas, trace amounts of vaporized amine-based solution and water travels through a chimney tray and enters the top packed bed. This packed bed is the wash section of the column, where wash water is used to recover the vaporized amine and water. A wash water circulating pump circulates the wash water between the absorber and wash water cooler.

4.2.16 Treated flue gas is vented to the atmosphere via the stack on top of each absorber at a temperature of approximately 37 °C. An early evaluation of the potential frequency of visible plumes from the final flue gas discharge from the CCP has been undertaken, as presented in the **Appendix 8B**: Operational Air Quality (ES Volume I – **Application Document Ref. 6.3**). This will be further evaluated at the detailed design stage and if required, appropriate mitigation employed.

Carbon Dioxide Stripper

4.2.17 Rich solvent leaves the bottom of the absorber and is routed to the rich to lean amine solution cross heat exchanger which increases the efficiency of the

process by heating the rich amine to >100 °C using the heat in the lean amine stream from the stripper. The pre-heated rich amine enters the stripper below the wash section of the column through a liquid distributor and flows down through the packed beds counter-current to the vapour from the reboiler releasing the absorbed carbon dioxide. The lean amine from the bottom of the stripper is transferred to the rich to lean solution cross heat exchanger, where it is cooled against the rich amine from the absorber train.

4.2.18 To remove impurities from the amine system, ~10% of the cooled amine is routed to the amine filter package. This removes suspended solids and high molecular weight amine degradation products.

Stripper Overhead Condenser

4.2.19 The overhead vapour from the stripper at ~100 °C and 0.8 barg is cooled to ~35 °C in the overhead condenser, condensing some of the water content. The two-phase enters the separation drum (separating the product gas which is routed to the carbon dioxide compression/ dehydration unit).

Amine Reclaimer

4.2.20 The amine-based solution degrades in the presence of different elements that lead to amine oxidation to salts, thus a purification stage is necessary to prevent the accumulation of such heat stable salts. The design assumes the reclaimer is a kettle-type reboiler where this purification process takes place. There is a feed of steam, water and sodium hydroxide to feed the reactions and processes required to allow for the recovery of part of the degraded amine-based solvent. The reclaimer is expected to operate on an intermittent basis when the content of dissolved salts exceeds a predefined value.

Carbon Dioxide Compressor

4.2.21 The wet carbon dioxide from the stripper reflux drum is routed to an intercooled carbon dioxide compressor. The captured carbon dioxide is compressed to meet the delivery pressure required for the 3rd party carbon dioxide export pipeline.

Dehydration Unit

4.2.22 A dehydration package is needed for reducing the water content in the carbon dioxide stream to 50 ppm (wt.) to assure that condensation in the carbon dioxide pipeline does not occur. At this concentration, the dew point is at approximately -46 °C, which makes condensation unlikely.

4.2.23 A glycol-based dehydration package, being a mature technology in natural gas dehydration processes, is well suited to be used for this application. For the expected operating temperatures, triethylene-glycol (TEG) is better than other glycol-based absorbents. This package is installed after the second intercooling stage of the carbon dioxide compression package. In doing so, the pressure remains below the critical point for carbon dioxide.

Steam Cycle

4.2.24 A supply of the order of 95 kg/s of low pressure steam (203 MW heat) is assumed for the amine regeneration process.

Cooling System

4.2.25 The amine-based CCP process has a cooling duty, which is estimated at 477 MWth. The CCP is proposed to use hybrid cooling towers to address main cooling demands within the CCP process which comprise:

- flue gas DCC cooler;
- lean solution to absorber cooler;
- stripper overhead cooler; and
- carbon dioxide compression intercoolers.

4.2.26 Space has been allocated for the cooling towers needed to meet the cooling demand of both the CCGT and CCP.

Compressed Air System

4.2.27 There is no requirement within a standard amine-based CCP for any compressed air for process purposes, but only for the supply of instrument air and general service air to the CCP. This requirement shall be determined at the detailed design stage. Depending on the exact requirements, e.g. the number and duty of air actuated valves; this may be met by connecting to the compressed air services of the Proposed Development, or by installing a new dedicated system for the CCP.

4.2.28 Sufficient space has been allocated for a new compressed air system.

Water Treatment

Raw Water

4.2.29 The Proposed Development will have a make-up raw water demand of approximately 840 t/h. This water shall make up for evaporative losses within the hybrid cooling towers as well as the small losses in of the amine/ water solution loop caused by amine degradation or carry over.

4.2.30 The increment on raw water abstracted by the Proposed Development to supply the CCP in addition to the CCGT operating alone has been included by the Applicant in the water demand assessment. The level of water treatment necessary for the CCP, including filtration and chemical dosing, will depend on the water quality at the abstraction site.

Demineralised Water

4.2.31 Some studies suggest that demineralised water quality is not required for the amine solution make-up water and only good quality water is required (IEA GHG, 2007). Should demineralised water quality be required, it is likely to be minimal with process water re-use prioritised, however there is sufficient space in the Proposed Development layout (within **Work No. 1E** as shown on the Works Plans (**Application Document Ref. 4.3**)) to include a dedicated water treatment plant, for production of up to 75 t/hr, which is estimated to require an area of circa 30 m x 50 m.

4.2.32 In normal operation, the water make-up is negligible as excess water in the DCC will be used for supplying the majority of water makeup requirements.

Wastewater

4.2.33 The detailed design of the CCP will include appropriate surface water drainage systems including oil interceptors as necessary, consistent with surface water drainage systems for power stations in general. Space provision for site drainage e.g. surface water and process water drains has been included in the footprint allocation for the CCP.

4.2.34 Wastewater will be generated from the cooling of the flue gas resulting in partial condensation of water vapour within the DCC. The volume of wastewater generated will vary with ambient conditions but is not likely to exceed 265 t/h. The wastewater treatment requirements are identified below in Table 1.

Table 1: Indicative Wastewater Output

Wastewater Stream	Estimate Mass Flow Rate / kg/s
Hybrid Cooling Tower blowdown	46
Effluent from Water Treatment Plant	27

4.2.35 The wastewater drain will be relatively clean although may have a slightly elevated pH. It is envisaged it will be routed to an effluent treatment plant prior to discharge.

Hazardous Waste Streams

4.2.36 The standard amine-based process includes a reclaimer for recovery of amine-based solution and removal of degradation products, solids and salts formed in the carbon capture process. This operation will generate a low volume effluent stream which will require treatment prior to off-site disposal via a licensed waste contractor.

4.2.37 Activated carbon is also consumed in the active carbon filters for the circulating amine-based solution. A slip-stream is constantly directed to a mechanical prefilter and then to the active carbon filter for removal of solids delaying the reclaiming activity. It is estimated that 0.08 kg of carbon per tonne of captured

carbon dioxide will be consumed. This solid waste material shall be disposed of for off-site regeneration/ recycling via a licensed waste contractor.

Electrical

4.2.38 In addition to the utilities described previously, the CCP will require the following utilities.

- electrical power distribution system; and
- fire protection and monitoring system.

4.2.39 The total power requirement of the CCP is approximately 50 MW. Further detail of individual users is presented in Table 2.

Table 2: CCS Electrical Power Consumption

CCP Equipment Items	Estimated Electrical Consumption / MW
Carbon Dioxide Compressor	19.9
Solvent Recirculation Pumps	2.3
Booster Fan	10.6
Hybrid Cooling Tower Fan Motors	3.1
Cooling Water Circulation Pumps	8.8
DCC Water Pump	2.6
Miscellaneous	2.6
Total	**50.0**

4.2.40 It is currently proposed that the electrical demand of the CCP is taken directly from the output of the generating station, reducing the export capacity to National Grid accordingly.

Pipework

4.2.41 Space provision for plant pipe racks has been included in the footprint allocation for each piece of equipment and is shown in **Appendix A**.

Control and Instrumentation

4.2.42 The control and instrumentation system for the CCP is anticipated to be incorporated into the distributed control system of the Proposed Development, i.e. the control room. However, space is available on the CCP for standalone control equipment should this be required.

Plant Infrastructure

4.2.43 It is anticipated that major plant may be delivered by road; additionally, it is proposed to include temporary retention and use of an existing Waterborne Transport Offloading Area and additional Abnormal Indivisible Load (AIL) route. There are not considered to be any access constraints that could impede any future construction activities.

4.2.44 The provision of space for additional plant infrastructure is illustrated in the illustrative site layout in Appendix A.

4.2.45 The final provisions for plant infrastructure will be detailed in the final design of the CCP.

4.3 Assessment of a Suitable Offshore Area for Carbon Dioxide Storage

4.3.1 The maximum theoretical volume of carbon dioxide anticipated to be captured during the lifetime of the Proposed Development is 50.7 million tonnes (assuming approximately 253 tCO_2/hour from the plant units, a maximum of 8,000 operating hours per year and a 25-year design lifetime).

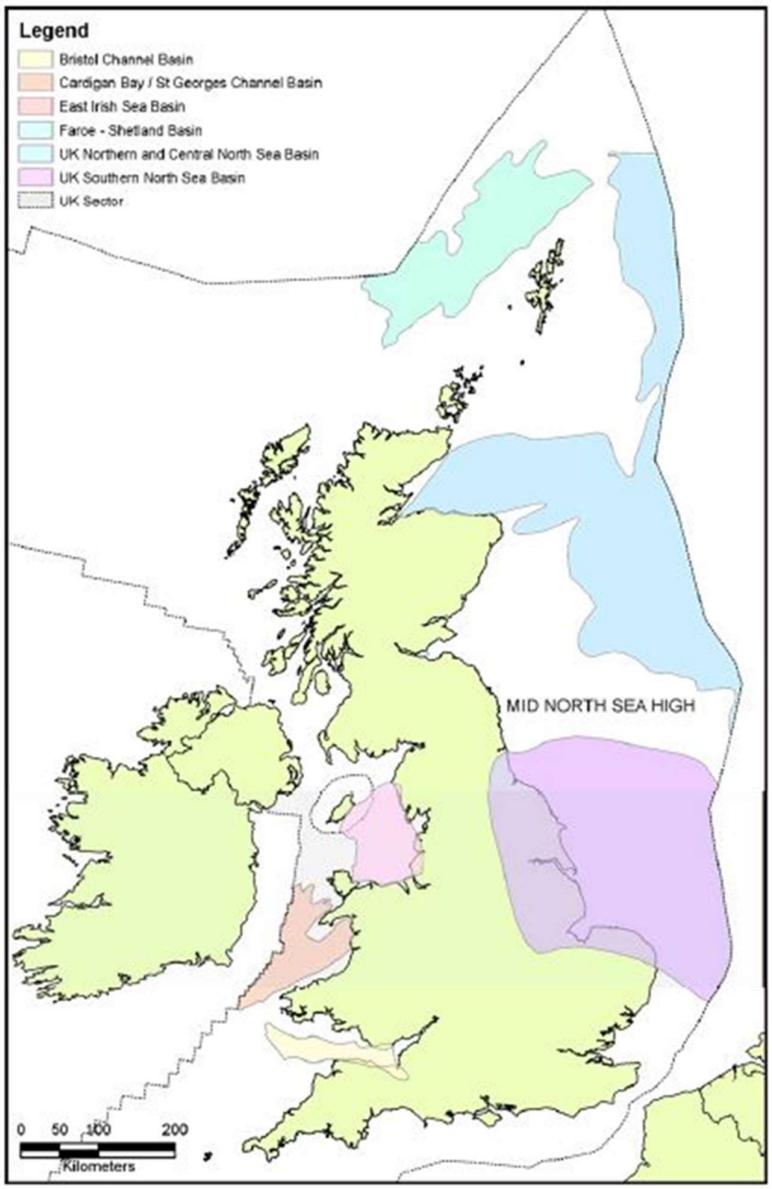
4.3.2 The UK's major potential sites for the long-term geological storage of carbon dioxide are offshore depleted hydrocarbon (oil and gas) fields and offshore saline water-bearing reservoir rocks/ aquifers.

4.3.3 Oil and gas fields are regarded as prime potential sites for carbon dioxide storage for the following reasons:

- they have a proven seal which has retained buoyant fluids, in many cases for millions of years; and
- often a large body of knowledge and data regarding their geological and engineering characteristics has been acquired during the exploration and production phases of oil and gas development.

4.3.4 As shown in **Figure 1** most of the UK's large offshore oil fields are mainly in the Northern and Central North Sea Basin. The UK's offshore gas fields occur mainly in two areas: the Southern North Sea (SNS) Basin and the East Irish Sea Basin. The DECC CCR guidance (DECC, 2009) suggests that the simplest and most appropriate means of demonstrating there are 'no known barriers' to carbon dioxide storage is by delineating on a map a suitable storage area in either the North Sea or Irish Sea (Morecambe Bay). Within this delineated area, applicants are advised to identify at least two fields or aquifers, with an appropriate carbon dioxide storage capacity, which have been listed in either the 'valid' or 'realistic' categories in the DTI's 2006 study of UK Storage Capacity (BGS, 2006), which is provided in Annex D of the CCR Guidance.

Figure 1: Major Sedimentary Basins of the UK Continental Shelf (BGS, 2006)



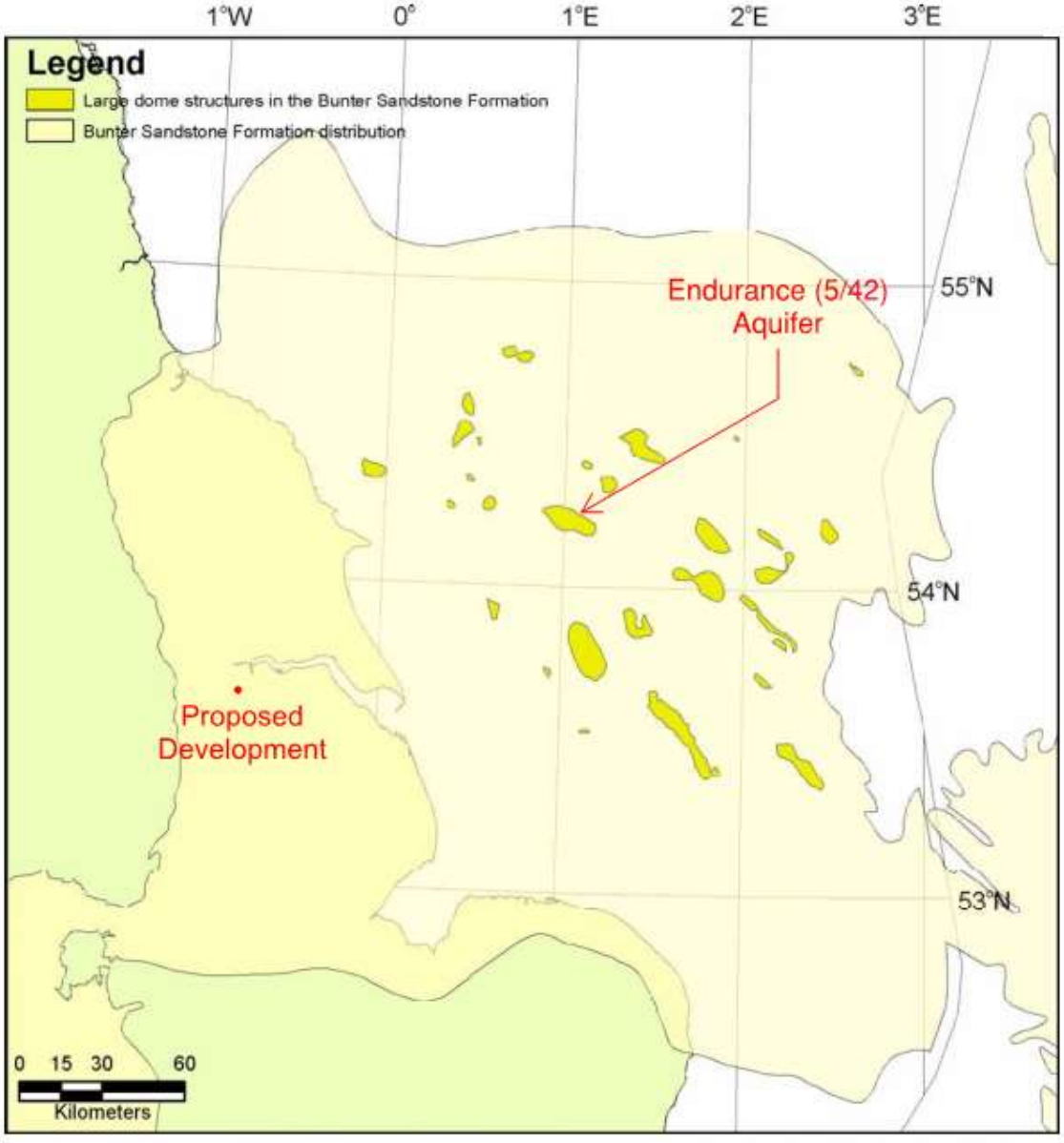
4.3.5 The Proposed Development is located in Keadby, North Lincolnshire and therefore the nearest hydrocarbon fields and saline aquifers are located in the SNS Basin.

4.3.6 The carbon dioxide storage location currently proposed by the ZCH Partnership for the Proposed Development is the Endurance saline aquifer within the Bunter Sandstone Formation in the SNS basin (formally identified as 5/42 – refer to **Figure 2**). The estimated total storage capacity of this storage location is approximately 2,700 million tonnes based on the examination as part of the Field Development Report for the White Rose CCS project (DECC, 2016).

4.3.7 Based on the total carbon dioxide storage requirements of the Proposed Development (50.7 million tonnes), the Proposed Development will use approximately 2.0% of the overall capacity of the Endurance saline aquifer.

4.3.8 The location of the Endurance saline aquifer is illustrated in **Figure 2**.

Figure 2: Map of storage sites within the Bunter Sandstone Formation with the location of the Endurance Aquifer (BGS, 2006)



4.3.9 In accordance with the CCR Guidance, the Bunter Sandstone Formation aquifer above is identified as having great potential as a carbon dioxide storage location in the DTI report (BGS, 2006).

4.3.10 Under the CCR Guidance, the storage assessment should be reviewed on an ongoing basis as part of the two-yearly Status Reports, with a view to incorporating developments in the updated design for the CCP. The Proposed Development as part of the ZCH partnership is intended to be the initial user of the Endurance carbon dioxide store, therefore the ongoing review is not considered necessary in this case.

4.4 Assessment of the Technical Feasibility of Carbon DioxideTransport

Overall Route

4.4.1 There are various options available for transporting carbon dioxide from point of capture to final geological storage, including onshore and offshore transportation by pipeline, and offshore transportation by pipeline or shipping.

4.4.2 It is intended that the carbon dioxide captured from the Proposed Development will be transported to the storage site via onshore and offshore pipeline, and separate consents for the routing, construction and operation of the onshore and offshore pipelines are being progressed by other parties in the ZCH Partnership.

Predominantly Onshore Transport Prior to Transition

4.4.3 ZCH Partnership is a consortium of energy and industrial companies, including the Applicant, with a shared plan to decarbonise industrial emissions. As part of the consortium, NGC is preparing a DCO application for the construction and operation of the 'Humber Low Carbon Pipeline' which once developed, would serve a number of key energy and industrial carbon dioxide producers, including the Proposed Development, prior to transition to offshore transport at Easington, north of the Humber Estuary for sequestration by the NEP within the Endurance saline aquifer.

4.4.4 Developing networks where clusters of power stations or other heavy industry adopting CCUS could use the same pipeline infrastructure is the most cost-effective solution for CCUS deployment compared to each installation building its own separate pipeline.

4.4.5 The final route of the Humber Low Carbon Pipeline is subject to ongoing routing and siting feasibility but is proposed to include connections to Drax at Selby, and to British Steel at Scunthorpe, located to the north-west and south-east of the Proposed Development Site respectively, before onward routing from Scunthorpe to Easington via Immingham.

4.4.6 **Work No. 7B** (**Application Document Ref. 4.3**) provides sufficient space for NGC to build a carbon dioxide AGI for the Proposed Development's connection to the Humber Low Carbon Pipeline (subject to finalisation of the ongoing routing and feasibility work by NGC).

Predominantly Offshore Transport

4.4.7 The offshore pipeline would run north-eastwards from Easington on the Humber coast, towards the Endurance storage site (the proposed carbon dioxide storage location).

4.4.8 A sub-sea pipeline would typically be laid using specialist trenching and laying barges. Where the level of disruption to environmentally sensitive areas (which is typically caused by trenching) is deemed to be unacceptable, other techniques such as thrust boring or directionally drilled boreholes may be feasible. Both boring methods avoid the need to disturb existing habitats. If these alternative boring techniques are not feasible, it is envisaged that construction would be planned around relevant breeding and migration seasons. This would be established and considered at all stages of the outline design, EIA and subsequent detailed design of the offshore infrastructure.

4.4.9 Navigation of wind farm sites and associated cabling, dredging areas, existing pipeline infrastructures and disposal sites via the proposed route would be feasible. Expertise in the laying of natural gas and oil pipelines in the SNS Basin would be expected to provide the techniques and expertise required to accomplish this.

4.4.10 The routes of shipping lanes are not anticipated to be a significant barrier to this form of transport, because the pipeline would run along the seabed at a depth sufficient to allow ships free passage. The impacts of the offshore carbon dioxide pipeline would be minimised by keeping the route of the pipeline a sufficient distance away from the shore so as not to impact any designated coastline. It is therefore considered that a feasible route exists to remove the captured carbon dioxide from the Proposed Development to the storage site identified.

5.0 ECONOMIC ASSESSMENT

5.1 Overview

5.1.1 The CCR Regulations require the developer to assess the likelihood that it will be economically feasible to link any proposed power station to a full chain CCUS within the lifetime of the power station, considering the retrofit of capture equipment, carbon dioxide transport and storage.

5.1.2 In applying for a DCO for the Proposed Development, the Applicant has invested in de-risking the deployment of CCS technology through the dedication of space and through seeking powers for the CCP development. The Applicant is proposing to further invest in the construction, operation and maintenance of CCP, including carbon dioxide compression facilities and connection to third party carbon dioxide export and storage infrastructure, subject to Government support and the corresponding third party investment and powers required for the balance of full-chain CCUS.

5.1.3 The Dispatchable Power Agreement (DPA), currently under development by BEIS (BEIS, 2020), is proposed as the key tool used to encourage low carbon electricity generation in the UK by advancing investment in power generation plant with CCUS, under the Contract for Difference (CfD) regime. This is intended to incentivise low carbon dispatchable operation within the merit order. With carbon price rise, as expected in the long-term, the dispatch decision should be more favourable for abated plant over unabated plant, and supplementary revenue will be provided through consumer subsidies.

5.1.4 The Government CCS Infrastructure Fund (BEIS 2021) is intended to support the establishment of two CCUS clusters and selection of eligible and evaluated Phase-1 power CCUS projects is anticipated in Q3/4 2021. The economic evaluation of the Proposed Development is subject to the outcome of this process.

5.1.5 The economic viability of the Proposed Development as a whole is therefore contingent on the outcome of the cluster selection process under the Government CCS Infrastructure Fund and negotiations under the Dispatchable Power Agreement, as well as the longer-term price of carbon.

6.0 HEALTH AND SAFETY ASSESSMENT

6.1 Pipeline

6.1.1 It is likely that the onshore and offshore carbon dioxide transport from the Proposed Development Site will be in a 'dense phase', i.e. at a pressure greater than 73.9 bar.

6.1.2 Carbon dioxide pipelines are not currently widely deployed in the UK and only some pipeline design codes include it as a relevant fluid within their scope. European Standards implemented in the UK as British Normative Standards (BS EN series) and supported by published documents (such as the British Standards PD series) provide a sound basis for the design of pipelines.

6.1.3 The CCR Guidance states that, until the health and safety requirements of pipelines conveying dense phase carbon dioxide have been considered in more depth, such pipelines should be considered as conveying 'dangerous fluids' under the Pipeline Safety Regulations 1996 (PSR) (HSE, 1996), and 'dangerous substances' under the Control of Major Accident Hazards Regulations 2015 (COMAH).

6.1.4 The 'Comparison of risks from carbon dioxide and natural gas pipelines' (Health and Safety Executive (HSE), 2009) concluded that a loss of containment event from a dense or supercritical phase carbon dioxide pipeline presents a similar level of risk to a release from a high-pressure natural gas pipeline. As such, designers of carbon dioxide pipelines should consider applying a similar fluid hazard categorisation (chosen from an established pipeline design code) to that applied to high pressure natural gas pipelines.

6.1.5 The pipeline would therefore be considered to be a Major Accident Hazard Pipeline (MAHP).

6.1.6 When undertaking the detailed design of the pipeline route, it is therefore recognised that the pipeline operator must pay due attention to the following potential requirements:

- installation and frequency of emergency shut-down valves;
- the preparation of a Major Accident Hazard Prevention Policy (MAPP); and
- ensuring the appropriate emergency procedures, organisation and arrangements are in place.

6.1.7 In addition, the Local Authority, which would be notified by the HSE of a MAHP, must prepare an Emergency Plan.

6.1.8 The Hazard Assessment undertaken for the Proposed Development, based on HSE modelling, has informed the consultation distances. Potential accident scenarios will be further evaluated, and potentially significant effects will be mitigated; these would be undertaken at the detailed design phase of any CCUS transport network.

6.2 On-Site

6.2.1 There is the potential for dense phase carbon dioxide to be present in pipework on-site once it has been captured and compressed prior to transport. Whilst carbon dioxide is not currently classified as hazardous, BEIS and the HSE recognise that an accidental release of large quantities of carbon dioxide (particularly in dense-phase) could result in a major accident.

6.2.2 No bulk storage of dense or gaseous phase carbon dioxide is proposed for the Proposed Development. The only 'stored' carbon dioxide at the Proposed PCC Site would therefore be the inventory in the CCP and on-site pipework, and this is envisaged to be less than five tonnes. It is envisaged that the Proposed Development will require consent under the Planning (Hazardous Substances Consent) 2015 Regulations regime and may trigger the need for lower tier COMAH licensing. This will be determined at the FEED stage.

6.2.3 A Health and Safety Plan covering the works, commissioning and operation of the Proposed Development will be prepared by the Applicant. For design and construction, a competent and adequately resourced Construction (Design and Management) (CDM) Coordinator and Principal Contractor will be appointed. The Applicant will monitor that its own staff, its designers and contractors follow the Approved Code of Practice (ACoP) laid down by the CDM Regulations 2015.

6.2.4 Written procedures clearly describing responsibilities, actions and communication channels will be available for operational personnel dealing with emergencies. Procedures will be externally audited, and contingency plans written in preparation for any unexpected complications.

6.2.5 The Proposed Development is using 'safety in design' principles to take into consideration safety issues and risks within the ongoing design, to reduce risks from the installation, as a whole, to as low as reasonably practicable (ALARP). As part of the layout evolution, the following safety in design mitigation hierarchy has been adopted:

- eliminate a hazard; in preference to;
- control the hazard; in preference to;
- provide personal protective equipment (PPE).

6.2.6 Design mitigation at the current concept design stage includes consideration of potential carbon dioxide releases and includes, (but is not limited to):

- careful equipment and material selection;
- siting of high-pressure carbon dioxide equipment considering areas of potential exposure and prevailing wind direction;
- incorporation of gas leak detection systems; and
- consideration of venting arrangements.

6.2.7 As the design of the Proposed Development progresses, further consideration will continue, potentially including additional dispersion modelling to confirm whether design mitigation is considered ALARP for the installation as a whole (i.e. future site users and general public). Further detailed evaluation and quantitative risk assessment will continue throughout the FEED stage when the Proposed Development is further defined.

7.0 CCR REVIEW

7.1.1 As the Proposed Development is carbon capture equipped and will be built as a CCUS project, with **Work No. 1C** identified for the CCP in the Works Plans (**Application Document Ref. 4.3**), it is considered that there is no need to undertake regular reviews of CCR status in the future.

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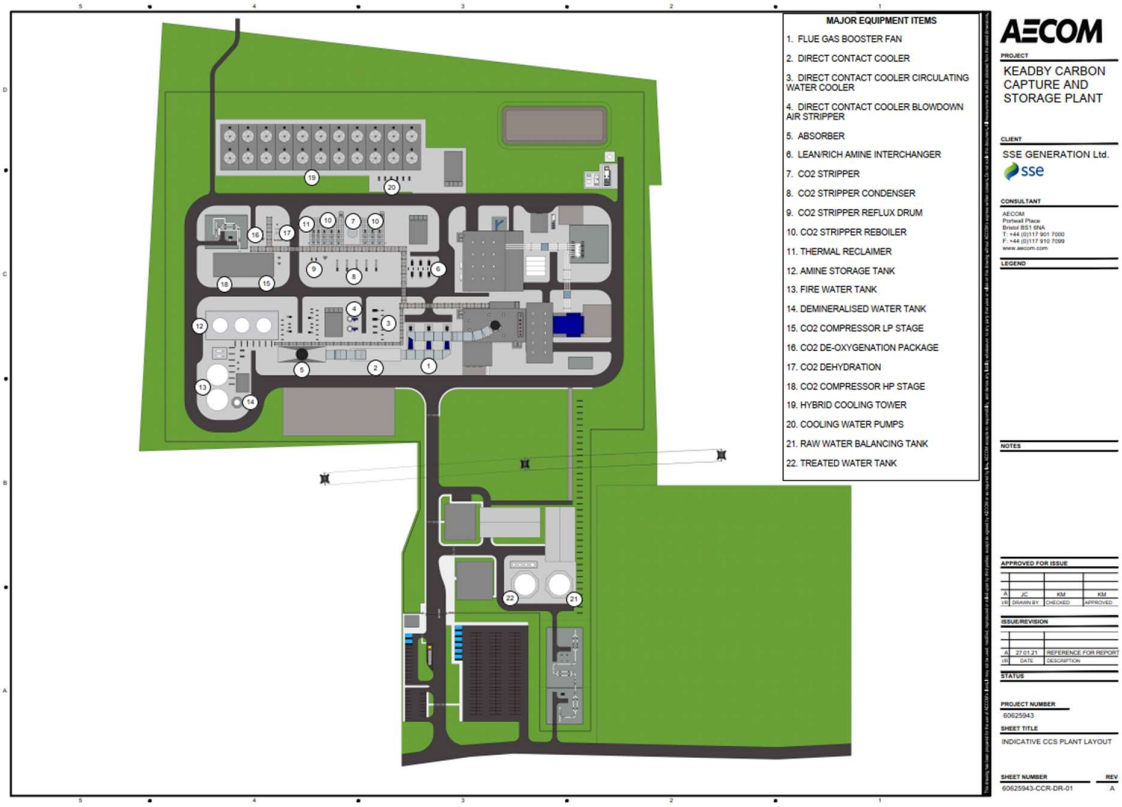
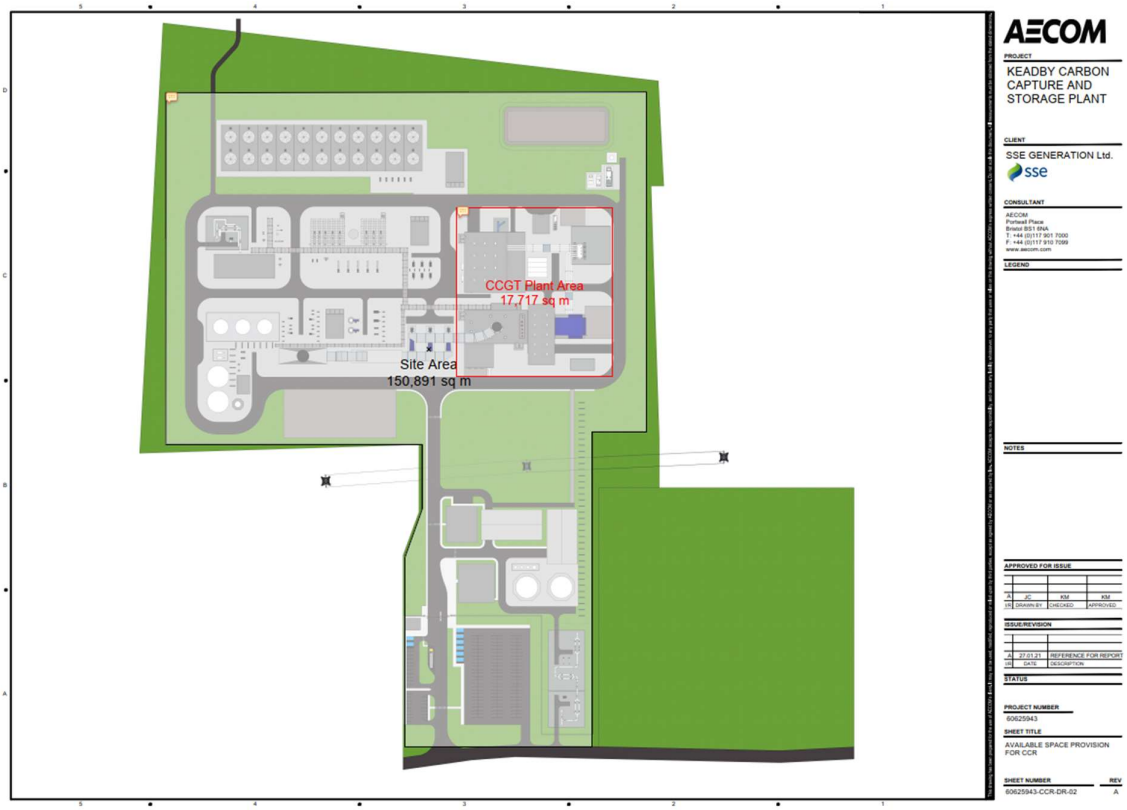
APPENDIX A: CCR SPACE ALLOCATION AND INDICATIVE LAYOUT




CCGT Plant Area
17,717 sq m
Site Area
150,891 sq m
AECOM
PROJECT
KEADBY CARBON CAPTURE AND STORAGE PLANT
CLIENT
SSE GENERATION Ltd.
CONSULTANT
LEGEND
NOTES
APPROVED FOR ISSUE
ISSUE/REVISION
STATUS
PROJECT NUMBER
60625943
SHEET TITLE
AVAILABLE SPACE PROVISION FOR CCR
SHEET NUMBER
60625943-CCR-DR-02