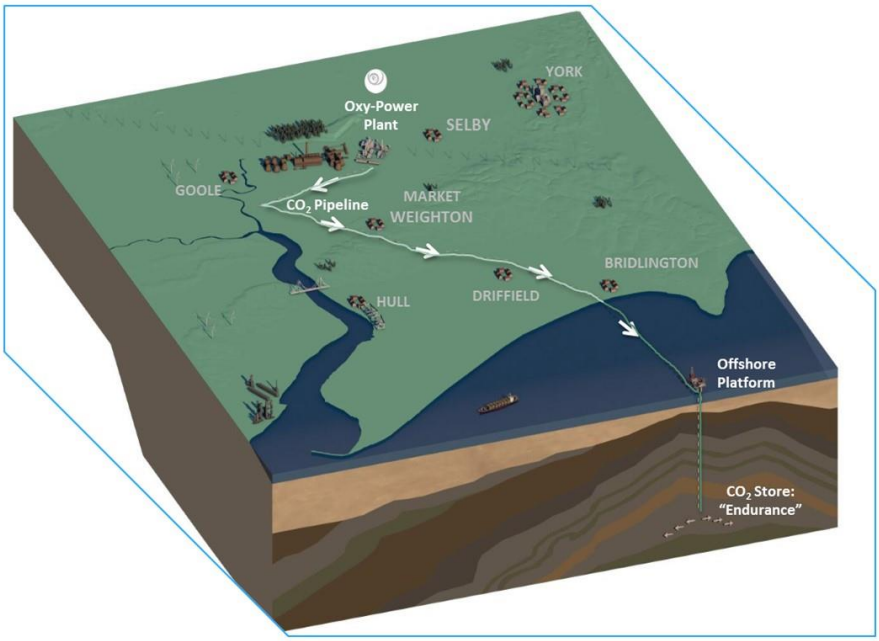
March 2016

WHITE ROSE

K.06 Full-chain FEED risk report

Commercial, Project Management



CAPTURE POWER

drax

BOC
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Contents

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Glossary or Key Words

Key Word	Meaning or Explanation
Authority	Department of Energy and Climate Change (DECC)
CfD	Contract for Difference as defined in Great Britain Electricity Market Reform legislation and regulations
Carbon Dioxide	A greenhouse gas produced during the combustion process
Carbon Capture and Storage	A technology which reduces carbon emissions from the combustion based power generation process and stores it in a suitable location
Coal	The fossil fuel used in the combustion process for White Rose
Consents	Permissions and approvals required for the project to proceed
Development Consent Order	A statutory instrument granted by the Secretary of State to authorise the construction and development of a Nationally Significant Infrastructure Project. The natures of these projects are defined by sections. 14-30 of the Planning Act 2008
Environment	The natural world, as a whole or in a particular geographical area, especially as affected by human activity
Full Chain	A complete CCS system from power generation through CO_2 capture, compression, transport to injection and permanent storage
Key Knowledge	Information that may be useful if not vital to understanding how some enterprise may be successfully undertaken
Project Contract	A contract to be entered into between the Authority and the Project developer pursuant to the CCS competition and governing Authority funding support and other aspects.
Storage	Containment in suitable pervious rock formations located under impervious rock formations usually under the sea bed
Transport	Removing processed CO_2 by pipeline from the capture and process unit to storage
Oxy Boiler	The boiler within the OPP capable of producing full load in either the air or oxy-fired mode of operation
Oxy-firing	The use of oxygen (instead of air) in the combustion process
Oxyfuel	The technology where combustion of fuel takes place with oxygen replacing air as the oxidant for the process, with resultant flue gas being high in CO_2
Oxy Power Plant	A power plant using oxyfuel technology
White Rose	The White Rose Carbon Capture and Storage project

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Executive Summary

The Full chain FEED risk report was generated as part of the Front End Engineering Design (FEED) contract with the Department of Energy and Climate Change (DECC) for White Rose, an integrated full-chain Carbon Capture and Storage (CCS) Project. This document is one of a series of Key Knowledge Deliverables (KKD) from White Rose to be issued by DECC for public information.

White Rose comprises a new coal-fired ultra-supercritical Oxy Power Plant (OPP) of up to 448 MW_e (gross) and a Transport and Storage (T&S) network that will transfer the carbon dioxide from the OPP by pipeline for permanent storage under the southern North Sea. The OPP captures around 90% of the carbon dioxide emissions and has the option to co-fire biomass.

Delivery of the project is through Capture Power Limited (CPL), an industrial consortium formed by Alstom (subsequently General Electric (GE)), BOC and Drax, and National Grid Carbon Limited (NGC), a wholly owned subsidiary of National Grid.

This report provides an overview of risk management as practised in FEED including managing risks to FEED activities (FEED risks) as well as those to subsequent project phases, e.g., to implementation phase (Project Risks). The report also covers the deployed risk management process, selection of FEED scope as means to reduce risks as well as a narrative on management of the key FEED and Project risks.

Her Majesty's Government (HMG) Spending Review was set out on 25 November 2015 outlining its capital budget and priorities. A market announcement on the same day indicated that the £1 billion ring-fenced capital budget for the Carbon Capture and Storage Competition was no longer available, the Spending Review accordingly did not include such budget. This meant that the Competition could not proceed as originally envisaged. Following this decision, a notice of termination was issued on 23 December 2015 under the White Rose FEED Contract, which terminated accordingly on 25 January 2016, prior to the expected completion date of FEED. The Government and CPL are committed to sharing the knowledge from UK CCS projects, and this Key Knowledge Deliverable represents the learning achieved up to the cancellation of the CCS Competition and termination of the FEED Contract and therefore does not necessarily represent the final and completed constructible project.

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1 Introduction

1.1 Background

The White Rose Carbon Capture and Storage (CCS) Project (White Rose) is an integrated full-chain CCS project comprising a new coal-fired Oxy Power Plant (OPP) and a Transport and Storage (T&S) network that will transfer the carbon dioxide from the OPP by pipeline for permanent storage under the southern North Sea.

The OPP is a new ultra-supercritical power plant with oxyfuel technology of up to 448 MWe gross output that will capture around 90% of carbon dioxide emissions and also have the option to co-fire biomass.

One of the first large scale demonstration plants of its type in the world, White Rose aims to prove CCS technology at commercial scale as a competitive form of low-carbon power generation and as an important technology in tackling climate change. The OPP will generate enough low carbon electricity to supply the equivalent needs of over 630,000 homes.

White Rose is being developed by Capture Power Limited (CPL), a consortium of GE, BOC and Drax. The project will also establish a CO_2 transportation and storage network in the region through the Yorkshire and Humber CCS pipeline being developed by National Grid Carbon Ltd (NGC).

1.2 Scope

This risk report outlines the risk reduction achieved within FEED using brief discussions on key risks as logged in project's risk registers. The registers covered the full-chain CCS project and all project phases starting with FEED through to decommissioning and long-term post-closure CO_2 store monitoring. Evaluations of the efficacies of the deployed mitigation strategies have also been covered.

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2 Risk management process

A CPL risk management process for the FEED phase was established early in FEED as part of a CPL quality manual and communicated to the CPL team as well as to all sub-contractors (including advisors).

Table 2.1: CPL risk management process purpose and scope

Risk management process purpose and scope	
Purpose	As one of the main objectives of FEED Phase is risk reduction, the risk management process is particularly important to help achieve this. Active risk management, including the identification of all categories of risks (technical, commercial, financial, execution etc.) and the establishment of associated risk mitigation plans as well as regular assessment of those plans and the overall Project risk landscape, is fundamental to business success.
Scope	The risk management process covers both risks pertaining to the planned execution of FEED Phase activities as well as risks pertaining to subsequent Project Phases which are defined through the work performed in the FEED Phase.

Risk management was clearly integral to all FEED work-streams and this process reinforced the need for active risk management. Another key process objective was to provide a cross-functional platform for the identification, assessment and establishment of mitigation strategies and follow-up for key FEED and project risks. Key risks were logged in central FEED and project registers (as relevant) which, were available to the entire CPL team to facilitate project de-risking and to provide a central repository for assessing mitigation progress, a one-stop check-list as well as for management reporting (CPL board, Authority, project boards etc.) The risk process was owned and managed by a Risk Manager within the CPL organisation having the following responsibilities:

- Management of cross-functional risk sessions in the form of periodic risk workshops as well as activity / risk specific sessions.
- Management of CPL risk registers (FEED Risk Register & Project Risk Register) including follow-up as necessary on progress of identified mitigation strategies.
- Establishment of CCS risks list which contained certain specific risks associated with commercialisation of CCS technology. This list was intended to be the basis of risk sharing discussions between CPL, the Authority and other stakeholders.

As far as sub-contractors are concerned, the process did not require them to change their existing processes but clearly identified and established interfaces and other details (format, timing, extent etc.) for exchange of risk information.

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3 FEED scope selection

FEED for the full-chain project was scoped to meet overall FEED objectives and enable the project to proceed to the next phase (implementation). Scoping was largely performed before FEED commencement and was regularly interrogated as FEED progressed to ensure assessment and addressing of new risks and gaps that became visible or were anticipated. However, a tight control on scope changes was maintained to ensure that efficiency is maintained and unnecessary deviations avoided.

Key FEED objectives established at FEED start included overall risk reduction, achievement of a bankable risk profile, enabling funding and financing, cost-certainty enhancement, full-chain technical and commercial integration and preparation of a robust Project Execution Plan to support an on-time and on-budget project execution etc. The FEED was scoped and structured to target fulfilment of these objectives.

Summarised below is the contribution of FEED activities / scope to project risk reduction.

3.1 Project Management

A robust project management approach was key to ensuring an on-schedule and on-budget project completion. The need for a robust approach was more acute for the White Rose project considering its full CCS chain nature which, brings increased inter-dependencies and a larger number of interfaces as compared to a conventional power project. The intended project management approach is summarised in the Project Execution Plan (PEP) (a key FEED scope) and appropriately considered and included in all implementation contracts.

The starting point for establishment of an effective and efficient project management approach was the mapping of the entire project scope and potential contracting approaches. As options were considered the overlying imperative for CPL was to bundle scope into larger contracts to ensure that single competent organisations are responsible for managing them and thereby also minimising interfaces between individual sub-contractors as well as between CPL and sub-contractors. Where interfaces could not be eliminated, proven project management approaches were intended to be deployed and included in various contracts. To ensure that CPL is competently set up to be able to fulfil all its obligations (which would have been significantly greater than those of a traditional IPP) and thereby reduce risks to on-schedule and on-budget project completion, a hybrid project management approach combining responsibilities for the OPP and the full-chain was developed. This involved the deployment of developer teams, a project management contractor as well as other specialist consultants. The entire approach is summarised in the PEP which, when finalised, would have formed the basis for execution planning.

Summarising, a robust project management approach would have facilitated the following for subsequent project phases:

- Meeting EHS and quality targets.
- On-schedule and on-budget project progress especially on integration of full-chain.
- Management of already identified and newly discovered risks as well as opportunities.
- Management of periodic progress updates for stakeholders etc.

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3.2 Corporate, Legal & Political

The corporate, legislative, regulatory, political and funding associated risks the full-chain project would have faced post-FEED were either unique or more significant than those faced by conventional power (e.g., a new built coal or gas fired power plant) or oil and gas (e.g., a gas transmission pipeline, an offshore oil platform etc.) projects. For example, certain policy and regulations governing CCS projects were new, with a higher probability of potential modifications as the market developed. Additionally, funding contracts with the Authority and with the European Commission (NER 300) would have contained obligations some of which might have made the project susceptible to risks normally not seen on conventional projects. These aspects had to be carefully assessed in FEED and resources were devoted not only to compile but also follow the evolution of applicable regulations. Additionally, drafts of funding contracts were systematically reviewed to assess and compile potential risks including requirements that might have impacted or would have required a modification of conventional proven execution or operational work processes. The results of the assessment were fed back to the ongoing negotiations with an objective of agreeing alternative mechanisms that could have fulfilled stakeholder requirements without subjecting the project to undue risks.

Summarising, a systematic approach to assessing and mitigating these risks would have facilitated the following for subsequent project phases:

- Support on-schedule and on-budget project progress.
- Support establishment of a robust project execution plan.
- Fulfil stakeholder expectations.
- Enable the project to fulfil contractual requirements.
- Mitigating risks (already identified or new) and avoiding financial stress.
- Maintaining economic performance and project returns etc.

3.3 Environmental & Permitting

Certain aspects of the construction and environmental permits required for the project were novel as the OPP would have been the first supercritical as well as the first coal fired Oxyfuel power plant to be permitted in the UK. Similarly development of storage infrastructure would have involved the first storage permit for storing CO_2 in an offshore saline formation in the UK. It was therefore necessary that the permits and consents for the full-chain project were developed carefully and in detail during the FEED to avoid permitting conditions that unnecessarily constrain project construction, operation and decommissioning.

Permitting and consenting activities were already underway prior to FEED commencement and through this effort a detailed list of documentation and information necessary had been prepared. Flowing from this work, it could be ensured that the planning of technical FEED activities was already informed of the anticipated demands from the permitting work-stream. FEED planning also recognised that considering the novel nature of certain permitting activities, extended engagement with the authorities might be necessary. Additionally, as part of FEED planning and execution, sessions were organised with project teams to make them aware of the permitting regime in the UK, e.g. on the Development Consent Order, and develop a strategy to allow the project design to evolve during detailed engineering (part of construction phase) within the boundaries and conditions imposed by permits (developed based on FEED design).

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Summarising, an accurate environmental and permitting strategy and plan would have facilitated the following for subsequent project phases:

- Allow the full-chain project to be constructed and operated within the boundaries established by construction and environmental permits without unnecessary constraints.
- On-schedule and on-budget project progress.
- Responding to stakeholder expectations as agreed through permitting conditions etc.

3.4 Technical

FEED was scoped to provide sufficient technical definition to the full-chain project not only to support other FEED work-streams but also to ensure that potential technical risks or uncertainties for construction and operation phases are discovered, assessed and mitigated early. Though scoping established at FEED start could be largely maintained, certain adjustments were necessary as FEED progressed to be able to respond to a changing risk profile, to newly identified risks or to newly identified information requirements. Scope changes were however performed under a strict change control philosophy.

The level of technical definition necessary to be established during FEED varied from component to component. As an example, a demineralisation plant within the OPP did not require the same level of definition as a Gas Processing Unit (GPU) as the former uses conventional technology deployed at many stations whereas a GPU was integral to commercialisation of Oxyfuel technology. Based upon the assessed gap (objective vs. definition available through pre-FEED work), technical activities were scoped and allocated to the CPL team and FEED sub-contractors.

An enhanced emphasis was placed on technical work associated with integration of the full-CCS chain as these activities did not have precedents that could have been relied upon. Examples of full-chain integration activities include:

- Full-chain basis of design
- Full-chain operations and maintenance philosophy
- Full-chain control philosophy
- Full-chain availability philosophy and modelling
- Full-chain metering and monitoring philosophy
- Full-chain dynamic modelling
- Full-chain hazard identification study
- Full-chain CO_2 venting philosophy
- Full-chain commissioning and testing philosophy

Summarising, appropriate technical definition would have facilitated the following for subsequent project phases:

- Allow the full-chain project to be constructed within the boundaries established by construction and environmental permits.
- Enable robust EPC contracts de-risking CPL.
- Support establishment of a robust project execution plan.

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- Support on-schedule and on-budget project progress especially for integration of full-chain.
- Reduce impact from crystallisation of any known technical risk and reduce probability of discovering new technical risks etc.

3.5 Commercial

Achieving a robust project commercial structure was another key FEED objective. A robust commercial structure for the full-chain as developed through FEED and deployed in subsequent phases would have not only allocated risks to parties best placed to manage them but also ensured that the project could respond to risks and outcomes without undue stress. Implementation of these structure would have been through various contracts and agreements that CPL, its sub-contractors and other stakeholders would have developed, negotiated and entered into through FEED. Further, as mentioned in the next section, simulations to assess how the intended structures would have responded to potential scenarios were ongoing as part of the project's financial modelling. Robust commercial structures would have contributed to project risk reduction through facilitating the following for subsequent project phases:

- Protecting (or mitigating) the project from significant risks (identified or new) and avoiding financial stress.
- Maintaining economic performance and project returns.
- Ensuring risk ownership lies with a party best placed to manage it allowing an efficient and effective mitigation etc.

3.6 Financial

The project's financial model would have been largely locked (except for agreed adjustments) on CPL entering into a CfD with the Low Carbon Contracts Company and into the Project Contract with the Authority. All unforeseen deviations from the construction and operational plan could therefore have a potential financial impact that might not have been recoverable. It was therefore essential that the FEED interrogated a host of scenarios for multiple structuring options to ensure that the project is appropriately set-up to achieve certain minimum performance levels in pre-defined worst cases. The assessments were being performed using the project's financial model. The results of the modelling contributed to selection of appropriate commercial structures and would have facilitated the following for subsequent project phases:

- Protecting (or mitigating) the project from significant risks (identified or new) and avoiding financial stress.
- Maintaining economic performance and project returns etc.

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4 Project risk reduction

The project team maintained a central project risk register compiling key risks to the project through the FEED. This register was an important project development management tool and was regularly reviewed and updated. For clarity the project risk register did not include risks to FEED (e.g., to on time and on budget completion of FEED) but was focused at risks to post-FEED project phases including construction, operation, decommissioning, long term store monitoring etc.

Included here is a brief description of fifty key risks from the project risk register. For each risk the following details have been provided:

- Background and risk description
- Risk category (top level of the deployed risk breakdown structure)
- Risk score when the risk was identified
- Risk score at the point of FEED termination
- Mitigation plan
- Mitigation effectiveness assessment

Mitigation effectiveness assessment has been subjectively performed and the following effectiveness categories have been used in this report:

- **Effective** used where the deployed mitigation strategy has been assessed to be successful.
- **Partially effective** used where the deployed mitigation strategy has been assessed to be partially successful.
- **Assessment not possible at the point of FEED termination** used where either an assessment on effectiveness was not possible at the point of FEED termination because the mitigation strategy had not run its full course, or where the effectiveness of the mitigation strategy developed and deployed through FEED could have only been assessed in subsequent project phases.
- **Partially effective; full assessment not possible at the point of FEED termination**: this category flows from the previous bullet but has been used for a sub-set of risks where though a complete assessment was not feasible, a partial success was clearly visible.
- **Not effective** used where the deployed mitigation strategy has been assessed to be not successful.

The following probability and impact scoring approach was deployed for the project risk register.

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Table 4.1: Impact scoring approach for the project risk register

Score	Meaning	Potential loss	Schedule	Health & Safety	Environmental	Reputation
5	Critical	> £100m	> 9 months	Fatality	Major incident resulting in long-term / permanent damage. Likely to lead to EA prosecution.	National Impact, Major negative media attention and damage to company and project reputation.
4	Very high	> £50m - £100m	> 6 – 9 months	Multiple serious injury	Significant incident, widespread, medium-term damage. Stop/ Prohibition Notice issued. Potential EA prosecution.	National and Regional Impact, Significant negative media attention and damage to project reputation.
3	High	> £10m - £50m	> 3 – 6 months	Serious injury	Moderate Incident, short-term damage and remediation required. Improvement Notice issued.	Moderate Regional and Local Impact, negative local media attention. Local public action/ resistance.
2	Medium	> £1m - £10m	> 1 – 3 months	Lost time injury	Minor incident readily contained, minor environmental effect. Internal non-conformance raised.	Limited Impact, local public concern.
1	Low	> 0 - £1m	0 – 1 month	Medical treatment case	Slight Environmental Incident, observation or near miss.	Slight Impact, local public awareness, but no public concern.

Table 4.2: Probability scoring approach for the project risk register

Score	Meaning	Probability
5	Highly likely	> 75%
4	Probable	> 40% - 75%
3	Possible	> 15% - 40%
2	Unlikely	> 5% - 15%
1	Rare	> 0 – 5%

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The risk assessments compiled below also use the above scoring approach.

1. Full-chain engineering activities

Full-chain engineering activities to be executed during the construction phase were being scoped, assigned and dependencies established based upon work done in FEED. There was a risk that (considering a lack of precedents) gaps and misalignments are discovered during execution which might impact project completion.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain engineering activities	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

The mitigation strategy was based upon a detailed assessment and planning of execution work during the FEED phase. This included scoping, allocation, scheduling, interfaces and dependencies establishment, project management plan preparation etc. Work was also underway at the close of the technical FEED activities to identify and resolve any gaps and misalignments to ensure all necessary scope was contracted for the Implementation Phase.

2. Full-chain operating practices and procedures

The project would have included a first-time (in the UK) establishment of full-chain operating practices and procedures integrating generation facilities, CO_2 transport systems and CO_2 storage systems. This task would have also involved paying due consideration to a future expansion to a network tying in multiple emitters. There was a risk that this task was not appropriately scoped and gaps and/or issues are discovered which needed to be addressed and these would involve rework / outages.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain operating practices and procedures	Project management	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

The mitigation strategy that had been established (though not fully implemented at the point of FEED termination) included a detailed project management plan for the identified tasks with scoping, allocation, scheduling, interfaces and dependency establishment. The project was also planning employment of specialist consultants to support execution of these tasks as part of detailed engineering. Work was also underway to develop mechanisms that enable an early visibility as well as an efficient resolution of any gaps and misalignments.

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3. Management of engineering interdependencies between the OPP and T&S system

The OPP EPC contractor's and CO_2 T&S contractors' engineering activities would have required timely and defined inputs from each other. There was however a risk that one or more parties fail to provide required engineering inputs or data as required by other parties.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Management of engineering interdependencies between the OPP and T&S system	Project management	Probability: 3 - Possible Impact: 3 -High	Probability: 3 - Possible Impact: 2 - Medium	Effective

The mitigation strategy for this risk employed a combination of detailed execution planning (Project Execution Plan) undertaken during FEED and project management and reporting to be undertaken during the project construction phase. Specifically, work was underway to ensure project management interfaces are clearly defined together with establishment of mechanisms for early identification and mitigation of slippages. This was over and above clear identification of engineering interfaces aligned across all implementation contracts. As part of this a project execution management / reporting structure was also being assessed to allow monitoring of performance and identification of issues and their resolution across multiple contracts.

4. Management of construction interdependencies between the OPP and T&S system

Though OPP and onshore transport activities could largely progress independently of one another, the two systems would have to be mechanically connected and a section of the CO_2 pipeline would have run through the OPP laydown area and the OPP site both of which, would have been under the OPP EPC contractor's control. There was a risk that a construction delay relating either to the OPP or to the onshore transport impacts the other.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Management of construction interdependencies between the OPP and T&S systems	Project management	Probability: 3 - Possible Impact: 3 -High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective

The strategy to mitigate this risk was based upon co-ordinated planning with the development of flexibility and back-up options and securing those through contracts. The planning was performed with due consideration to programme buffers and allocation of contingency. This was reinforced by the allocation of implementation roles agreed within the Construction Design and Management (CDM) framework.

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Additionally contractual arrangements between CPL and NGC were under development to ensure appropriate mechanisms for damages and compensation were in place.

5. Grid connection delay

There was a risk that National Grid Electricity Transmission would be late with consenting, constructing and/or commissioning of the grid connection and required network reinforcement, consequently delaying OPP commissioning and potentially full-chain commissioning.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Grid connection delay	Project management	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

Though the project's ability to manage this risk is limited, the mitigation strategy nevertheless was based upon a combination of a regular assessment of the available buffer and maintaining close contact with NGET on their progress of consenting and construction activities. An early date for back-feed power was also secured with export rights becoming available later, once network reinforcement was complete.

6. Project knowledge management

A large proportion of development work performed during FEED was unique to the project. There was a risk that valuable project knowledge is not passed on as the project transitions to the next phase. This was compounded by the fact that the team for the execution phase would be significantly larger with most members joining the project new.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Project knowledge management	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 – Unlikely Impact: 3 - High	Effective

The intended mitigation strategy involved a combination of handover plans and workshops and seeking to achieve appropriate level of continuity and/or overlap between teams when the project would have transitioned to the next phase. A key part of the mitigation plan was maintaining robust documentation with necessary knowledge, e.g., project execution plan, project risk register etc.

7. Management of Authority deliverables

Certain project technical documentation developed during detailed engineering was required to be submitted to the Authority for their project progress and assurance review. There was a risk that the

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Authority judges the submitted project documentation to be incomplete or have other comments thereby requiring rework or rectification programmes.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Management of Authority deliverables	Project management	Probability: 3 - Possible Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination

The mitigation primarily involved achieving clarity on contents and objectives for each of the documents contained in the list. This would have been achieved through preparation of detailed specification sheets for each deliverable. Documentation where ambiguity remains despite preparation of specification sheets were to be discussed for agreeing a way forward. The contractual submission dates would have considered preparation planning as well as constraints and dependent activities.

8. Contract management

The project developer would have entered into a Project Contract with the Authority covering project funding and other aspects specific to the project. There was a risk that the agreed reporting requirements under the Project Contract are or become overly onerous and different from those required for other purposes (e.g., lenders) causing a significant increase in resources required to fulfil the requirements.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Contract management	Project management	Probability: 3 – Possible Impact: 2 - Medium	Probability: 3 – Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination

The mitigation strategy involved agreeing clearly defined requirements and documenting them in the Project Contract. The engagement with the Authority would have reviewed the details, alternative ways of providing relevant information as well as update frequency for certain documents. Experience gained from reporting performed under the FEED Contract reporting would have also supported the engagement. Some progress had been made on this in negotiation with the Authority. The developer would have also ensured that all relevant requirements were passed down to the supply chain.

9. Labour discontent and strikes

It was recognised that the OPP site would have been one of the largest industrial construction sites in the UK with thousands working on power plant construction at its peak. Managing a large site requires careful planning and set-up with initial structuring and planning already developed during FEED. There was however a risk that the power plant site is still impacted by localised or regional labour discontent, blockages and strikes.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Labour discontent and strikes	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Assessment not possible at the point of FEED termination

The framework for construction practices and procedures was already developed during FEED involving both the OPP EPC contractor and the O&M contractor and a commitment to the NAECI as a “Blue Book” site. This also involved an engagement to understand the practices at nearby facilities. Based upon the developed framework, a consultation engagement with unions and relevant bodies was initiated and further rounds were planned after the completion of the construction execution plan. Alignment engagement with NGC was due on the planned construction regime for the pig-trap compound next to OPP site.

10. Availability of skilled labour

It was recognised that the OPP site would have been one of the largest industrial construction sites in the UK and would have required a sizeable amount of skilled labour for an extended duration. Other large infrastructure projects under construction at the same time, depending upon their location and exact timing might have constrained the availability of necessary manpower potentially leading to a cost and schedule impact.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Availability of skilled labour	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination

The risk and its impact is highly dependent upon project timing and the start of OPP construction. CPL required a turnkey delivery of the OPP from the EPC contractor with the construction risk managed appropriately. The EPC contractor had already initiated engagement with the construction market to establish initial construction planning and costing. CPL and EPC contractor’s teams continued to monitor the market and further engagement on construction and execution planning were planned as part of finalising the OPP EPC contract.

11. Project protestors causing disruption to project site

There was a risk that protestors opposed to new CCS generation capacity cause delays to project construction.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Project protestors causing disruption to project site	Corporate, Legal & Political	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

The project has consistently strived for a good engagement with the local community and also actively engaged with other stakeholders, e.g., through the DCO effort. To facilitate continuation of this practice, a detailed stakeholder management plan covering the construction phase was planned to be prepared as part of the FEED work. Progressing the activities outlined in the plan would have provided the project an opportunity to mitigate this risk. A visitor's centre was also planned to be built at the site to inform stakeholders as well as members of public about various project aspects.

Media reporting was also regularly scanned to establish if engagement and the communication plan needed augmentation. During project execution, close liaison with the law enforcement authorities would have also been maintained.

12. Introduction of new guidelines and standards for CCS

Considering the evolving nature of the industry and considering that the project was a commercialisation project, there was a risk that new technical standards / guidelines (including those that are currently being drafted or are currently not applicable) come into force after the Project Contract with the Authority is effective and these requirements might potentially have to be followed without any adjustments to the contract.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Introduction of new guidelines and standards for CCS	Corporate, Legal & Political	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

As part of FEED work, a landscape assessment for CCS technical standards and guidelines was being periodically performed by OPP sub-contractors and NGC as part of their regular work-processes. Additionally, NGC assessed and commented upon the draft ISO standard on CO_2 transportation and CPL assessed and commented upon the CO_2 transportation ISO standard as well as draft BAT guidance from EA. This practice would have continued during the construction phase as well. For a sub-set of standards and guidelines under preparation, an additional review looking at their likely impact when they come into force was performed as well. These assessments informed the project's position during contractual discussions.

13. Archaeological findings in the OPP laydown area

Archaeological findings potentially of interest were discovered in the OPP plant laydown area. There was a risk that North Yorkshire County Council (NYCC), Historic England (HE) and other bodies object during

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construction to the manner in which laydown areas are being used on account of archaeological findings in the area leading to construction bottlenecks and a reduction in net available laydown area.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Archaeological findings in the OPP laydown area	Environmental & Permitting	Probability: 3 - Possible Impact: 2 - Medium	Probability: 1 - Rare Impact: 2 - Medium	Effective

A clear plan was prepared to address this issue and minimise any likely impact once construction commences. Site information already available was reviewed and gaps established. Additional investigations as necessary were then conducted and facts and plans clearly laid out for the DCO. Through the DCO process, the project team engaged with HE and NYCC presenting plans to manage the issue. Any additional requirements originating from this engagement and the DCO would have been embedded in the OPP construction contract.

14. Electricity Market Reform (EMR) – Emissions Performance Standard (EPS) requirements

An emissions performance standard (EPS) which, imposes an annual limit on CO_2 emissions from new-build thermal power plants is an integral part of the EMR for the GB market. EPS limits do not present any problems for CCS enabled plants and additionally, the regulation provides for a three year exemption period for initial operation of CCS commercialisation projects. There was however a risk that OPP commissioning which is pre-operation and involves commissioning the station in air-mode before commencement of oxy-mode commissioning might be restrained by EPS requirements, thereby delaying the project.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
EMR – EPS requirements	Environmental & Permitting	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

As a first step, a detailed review of applicable requirements and regulations was launched. This was augmented by independent reviews of the requirements by technical and legal experts. This confirmed that the exemption period was not available until the full-chain was ready to commence commissioning. As a next step, potential plant operating profiles expected during commissioning were prepared and various scenarios investigated to assess the scale of challenge. As the applicable limit is an annual average, based on calendar years (or part years), the scenarios also included commissioning happening over different combinations of calendar months. Assessments and review were still ongoing at the point of termination of the FEED Contract.

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15. OPP detailed design within DCO boundary limits

DCO requirements prepared based upon FEED work establish boundaries, envelopes and limits for various aspects of the project's design. Detailed design and engineering for an OPP plant at this size would have been performed for the first time. There was a risk that detailed engineering points out that boundaries established as part of the DCO (especially on layout and building dimensions) cannot be met without substantial cost / time impact.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Detailed design within DCO boundary limits	Environmental & Permitting	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination

Project teams, including contractor teams located locally as well as abroad, were educated about the specifics of the DCO regime before FEED commenced and the message was reinforced at FEED kick-off. Experienced permitting professionals ably guided project teams with respect to the design approach necessary to minimise the risk of limits being exceeded at a later stage. This involved establishment of reasonable worst case envelopes for key design aspects (e.g. building dimensions, emissions, noise) to be included in DCO documentation. The agreed DCO requirements would have been reflected in construction contracts.

16. OPP technical integration

OPP design included plant and systems not required in conventional power plants including the Air Separation Unit (ASU) and the GPU both of which are process plants. There was a risk that OPP design integration (sizing, margins, interfaces, performances etc.) combining plants from process and power industries is inadequate.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
OPP technical integration	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 1 - Rare Impact: 2 - Medium	Effective

This risk was already assessed prior to FEED start and was to a significant extent mitigated through the structuring of the OPP design work performed as part of the FEED. The structuring included a series of topic specific (e.g., interfaces, sizing, margins etc.) cross-team workshops as well as common plant documentation (e.g., interfaces schedule, basis of design etc.) which, brought together various design teams working on OPP technical definition. Joint detailed design review meetings as well as an independent review by CPL's technical advisor were organised as well. Further, as part of the commercial work-stream it was decided not to contract for the OPP and the ASU separately and one EPC contract for the entire scope was sought with the design integration and performance responsibility lying with the OPP EPC contractor.

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17. Dense phase CO_2 analysis and flow measurement

Instrumentation vendors have only limited experience available with analysers and flow measurement for monitoring impure dense phase CO_2. There was a risk that employed gas monitoring equipment does not perform as expected which might lead to triggering of spurious trips or venting causing loss of revenue and potentially also leading to disputes between parties over the tariff metering.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Dense phase CO_2 measurement	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective

To mitigate this risk, it was ensured that relevant instruments are only selected after a detailed assessment performed with specialist vendors. Instrumentation selection was also included in scope of third-party quality assurance work performed on Gas Processing Unit design. Additionally regular market monitoring was being performed to keep abreast of new developments. Lastly operational planning included regular sampling and calibration and maintenance of adequate spares.

18. CO_2 T&S system – operating flexibility

The OPP would have operated in a dynamic electricity market environment with the requirement for flexible generation becoming ever more important. Flexibility was embedded in the full-chain basis of design (BoD) operational requirements and ranges. There was however a risk that the CO_2 T&S system might not respond to OPP operating requirements constraining its operation.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 T&S system – operating flexibility	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

The need for flexibility was clearly established in the full-chain BoD and the requirements were further discussed and elaborated in detail in the full-chain philosophies established early in FEED. These then provided the relevant inputs for FEED scoping and system design. End to end flow assurance simulations performed during FEED confirmed that the system would be capable of responding to the operational range set out in the basis of design. The need for enhanced simulations as a part of detailed design during the construction phase was also being assessed.

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19. Full-chain maintenance alignment

Economic modelling for the OPP as well as for the CO_2 T&S infrastructure required availability assessment for the combined full-chain to be performed during FEED before baseline models were locked as part of the Project Contract. There was however a risk that the respective maintenance profiles used as the basis for availability assessment cannot be maintained over the operational life of the project potentially leading to revenue shortages.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain maintenance alignment	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

An end to end operation and maintenance philosophy was established in order to guide the FEED work. This highlighted the principle that T&S maintenance could be performed “in the shadow” of planned OPP maintenance wherever possible or wherever appropriate and scheduled using a collaborative approach to maximise full chain availability. The need for a high availability CO_2 T&S system was recognised and the design executed accordingly as part of this exercise using value engineering as well as considering future operating scenarios where multiple emitters are tied into the network. The design developed ensured that full-chain operation could continue for all planned maintenance work on the T&S network. Further, the planning work for establishment of full-chain operating protocols included early communication of OPP planned outages to NGC to allow the full-chain the best opportunity to align planned outages within this window.

20. Full-chain operation

Integration of the full CCS chain and a corresponding risk reduction was one of the primary FEED objectives. However, despite the effort (philosophies, design, simulations, HAZID etc.) and the definition achieved, there was a risk that not all operating scenarios have been identified and assessed through FEED and operation and availability might be impacted.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain operation	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

The plan to revisit full-chain philosophies established at FEED start at the completion of FEED (in order to reassess and confirm their applicability based upon FEED work) and had largely been completed at the point the FEED was terminated. Planning for full-chain detailed engineering was under way including an assessment of dependencies between works to be performed by various contractors. A full-chain HAZOP

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study to be conducted as soon as reasonably practical during the construction phase was an integral part of this planning.

21. OPP site raising delay risk

The Environment Agency required the OPP site to be raised significantly from the current average height to mitigate the risk of flooding (including an allowance for climate change effects). This activity due to its nature carried two significant risks; firstly work progress is sensitive to weather conditions which, brings uncertainty. Secondly, site raising leads to consolidation of the existing soil. Though the quantum of consolidation and the time taken can be assessed using modern practices, uncertainties would have remained. The risks were further amplified by the nature of the project - the large site, large buildings and weights (power boiler, turbine-hall etc.) requiring massive foundations and extensive underground networks.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
OPP site raising delay risk	Technical	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Effective

A series of mitigation measures were identified and were under various stages of implementation. These included the use of one contractor for site raising and civil works, use of filling materials that are able to better withstand adverse weather conditions, trial consolidation tests during FEED and other appropriate planning measures. These mitigation measures together with best practices and available market experience ensured that the risk profile for CPL was manageable.

22. OPP commissioning

An OPP at this scale would have been commissioned for the first time anywhere in the world and there was a risk that commissioning and testing activities take longer than planned thereby delaying commencement of full-chain operation together with cost increase and delay in revenue.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
OPP commissioning	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

The mitigation was based upon a thorough interrogation and refinement of the OPP commissioning sequencing and planning within FEED. Wherever feasible and practical, dependencies between commissioning activities were reduced or eliminated (including full-chain commissioning dependencies). The agreed planning basis would have been appropriately included in relevant contracts.

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23. Updated Construction Design Management (CDM) requirements

The 2015 update to CDM requirements created the role of "Principal Designer" (an entity that can influence / make decisions on all design aspects) in addition to the role of "Principal Contractor". Construction work at and around the OPP site would have consisted of the OPP itself, interconnections to Drax power station and certain CO_2 transport infrastructure. There was a risk that the regime developed based upon the requirements does not work efficiently and/or there are disputes / claims between counter-parties if changes need to be made to design of individual scopes as arising from the Principal Designer role.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
New CDM requirements	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective

Considering the new regime, the unique nature of the project and lack of projects working to the updated regulations, specialist advice on the requirements and possible solutions was sought. A thorough and systematic review of options available was then conducted to select a structuring that most effectively mitigated this risk. The Health and Safety Executive (HSE) was then approached with the concept to agree the application of regulations to the project. The agreed concept was based upon CPL retaining the role of principal designer, however, with the responsibility for a compliant design remaining with the OPP supply chain and with NGC.

24. OPP plant type

White Rose OPP would have been the first of a kind thermal power plant to combine major equipment and plant modules hitherto supplied into two differently established industrial sectors (i) power, and (ii) chemical / petrochemical installations. There was a risk that O&M planning may inadequately address the hybrid combination of power and process plants and systems as combining operational practises and standards from different industries in one operation may cause confusion and give rise to mistakes in early stage operation.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
OPP plant type	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

Planning and scoping work to mitigate this risk through development of appropriate systems and standards as part of detailed engineering was underway. The use of a single contracting entity as operator, appropriate operating team selection and training and using a competent third-party to support / quality assure the developed systems was being assessed as well. Satisfying COMAH would have been an appropriate test as it involves competency assessment.

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25. CO_2 stream specification

The CO_2 pipeline materials, CO_2 well and the storage formation are sensitive to certain impurities and for this reason, the full-chain was designed to an agreed CO_2 specification informed by extensive R&D work performed by NGC. The primary sources for potential impurities were coal constituents and combustion by-products. Accordingly, the flue-gas treatment systems and the GPU within the OPP were designed to eliminate or reduce relevant impurities to acceptable limits. There was however a risk that despite appropriate OPP design, out-of-specification CO_2 enters the pipeline causing damage or reducing the design life of the system and its storage capability. In the shorter term it would also cause reduced availability of the full-chain as the transport and storage system operator might have refused to accept out-of-specification CO_2 and costs might have been incurred for remediation or repair.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 stream specification	Technical	Probability: 3 - Possible Impact: 5 - Critical	Probability: 2 - Unlikely Impact: 3 - High	Effective

A thorough review was carried out on the OPP design to obtain assurance with respect to the achievability, measurement and control of the CO_2 specification. In addition to the internal review by CPL and CPL's technical advisor, an additional independent review of the Gas Processing Unit design by a third-party specialist consultant was commissioned which also confirmed design suitability.

Further, in order to minimise the impact from any, however unlikely, out-of-specification event, it was being considered that independent CO_2 stream composition analysers be installed on both sides of the terminal point between the OPP and CO_2 transport infrastructure (with online exchange of signals) to ensure that both the OPP and the CO_2 transport infrastructure respond immediately and isolate the system at the first possible termination point to minimise the potential for impact to the onshore pipeline.

The specification for CO_2 composition had been agreed with NGC, and was based on research and study work they had carried out. NGC also planned to monitor for corrosion during routine pipeline inspection activities using in line inspection tools.

26. Overall metering concept

The Contract for Difference (CfD) proposed a clean electricity metering concept combining fuel, electricity, and captured CO_2 analysis and metering. The proposed formula, adapted from the standard EU ETS approach, combined both measured and calculated values along with continuous and batch measurements. While this approach is appropriate for EU ETS where the values are aggregated over a year's operation, it leads to inaccuracy and retrospective adjustment when applied to the 30 minute CfD settlement periods. There was a risk that the suggested approach would lead to the determined amount of clean electricity being less than actual clean electricity generated leading to the need for a higher nominal strike price. Lastly, the approach would have also unduly disadvantaged future CCS projects competing with other clean electricity technologies.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Overall metering concept	Commercial	Probability: 4 - Probable Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination

An alternative simplified approach, using a smaller number of measurements, all available in real time, and offering a reduced measurement tolerance was developed and presented to the Authority for its consideration. Feedback on this proposal was still pending at the point of FEED termination.

27. Full-chain commissioning alignment

Though the construction of the OPP, CO_2 transport infrastructure and CO_2 storage infrastructure could largely proceed independently of each other, the full-chain required alignment for achievement of milestones such as start of full-chain commissioning, full-chain testing as well as start of the CfD. There was a risk that CPL is unable to achieve an aligned completion, commissioning and testing milestone regime that works for all scenarios leaving the project exposed to claims / liabilities which are not backed-off. Lack of alignment may also hinder the ability to perform tests and plant modification, if necessary.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain commissioning alignment	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

As a primary mitigation measure the full-chain project execution plan was assessed for minimisation of dependencies between the OPP and CO_2 T&S infrastructure activities, e.g. completion of OPP commissioning largely independent of T&S infrastructure. Where dependencies could not be eliminated, concepts were developed to enhance certainty of a timely completion of full-chain activities. Attention was also paid to development of a clear completion definition and underlying planning for milestones that tie the full-chain together. Appropriate compensation and damages mechanisms were also being discussed between CPL and NGC. Lastly, as the risk was only inherent to anchor projects, appropriate use of Project Contract mechanisms was also proposed.

28. CO_2 T&S infrastructure risks in a multi-user environment

The CO_2 T&S system was intended to be oversized to allow future emitters to join the network thereby achieving significant economy of scale for T&S services and hence facilitating commercialisation of CCS. Operating a network however requires a different technical and commercial basis than a point to point solution with only one emitter using T&S services. There was a risk that CPL might be exposed to additional risks should availability of the T&S system be reduced in a multi-user environment.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 T&S infrastructure risks in a multi-user environment	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

Various scenarios that could cause a reduction in T&S system availability in a multi-user environment were under assessment distinguishing between events originating in the T&S system and events caused by other emitters. Commercial structures to mitigate this risk through provisions of a T&S Services Agreement between CPL and NGC were under development at the time of FEED termination.

29. Mandatory access requirement causing delays

Regulations governing mandatory third-party access (TPA) to the T&S system were already in place and there was a risk that exercising of such an access request by a third-party might delay the T&S infrastructure construction or if exercised during the operational phase might lead to operational down time (associated with a potential need to take the T&S system offline to implement necessary modifications). Any such down-time would have had an economic impact and potentially would also have impacted CPL's obligations under various contracts and agreements.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Requirement of mandatory access to T&S system causing delays	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination

A thorough review of the applicable regulations governing third-party access to the T&S system was commissioned and key findings discussed within the project team and with relevant specialists. Based on the assessment, potential scenarios were simulated to review likely impacts. It was clear that the T&S system would have to manage access requests for the project's operational phase as the network grew and potentially multiple emitters might be impacted by any downtime. Accordingly, the intended mitigation for CPL was to primarily address the risk through the commercial provisions of the T&S services agreement. For NGC, the intended mitigation of this risk was through the requirement for the TPA party to bear the implications arising from such access. In any case, the T&S system design included the use of multi-junctions etc. to minimise potential downtimes.

30. CfD indexation

The CfD is a long-term contract and includes pre-agreed mechanisms for adjustment of the strike price to reflect evolution in the project's cost-base. The standard form CfD uses 100% Consumer Price Index (CPI) but for White Rose the Authority suggested a use of CPI, a fuel index and a non-indexed (fixed) component. For fuel, CPL had proposed using an international coal price index but expressed in sterling

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terms using appropriate exchange rates. However this had not been discussed with the Authority by the time of FEED termination. There was a risk that the indexation mechanism, once finally agreed, does not provide adequate coverage against changes in the project's cost-base due to the nature of adjustment or due to use of indices not reflecting cost evolution or otherwise.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CfD indexation	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

To mitigate this risk a detailed review of the project's cost-base spanning the entire economic life of the project was undertaken using the project's financial model and the appropriate share for the three components. Market research was undertaken to identify a suitable fuel price index. This exercise also gained from the ongoing engagement with the supply chain on preparation of various implementation and operational contracts. The exercise did point to gaps which would have needed addressing to reduce risk of an economic impact. At the point of FEED termination, the project team supported by CPL's advisors was busy assessing availability and suitability of use of market instruments such as hedging, e.g., hedging Retail Price Index vs. CPI, currency hedging etc. as a mitigation option.

31. Insufficient demand for CCS results in no follow-on loads after CPL

White Rose was the anchor project for the CO_2 T&S system which was being designed over-sized to accommodate other future emitters in the region. There was a risk that there might be insufficient demand for CCS potentially arising from inadequate policy and financial measures from the government, resulting in no follow-on loads after CPL.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Insufficient demand for CCS results in no follow-on loads after CPL	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination

Although the approach of using White Rose as the anchor project and building an over-sized transport and storage system so that other CO_2 emitters could join appeared consistent with policies of both the UK Government and the EC, to help mitigate this risk CPL and NGC continued to work with the Authority to ensure that technical and commercial implications were understood and being developed appropriately. Work had also been progressed on the charging methodology to allow future customers to join the network.

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32. Transport and storage System uptime less than expected

There was a risk that the T&S system's operational availability was lower than expected, reducing the full-chain performance and leading to losses. As an example, an availability shortfall might have arisen from a significant outage causing maintenance work required to be performed outside of the planned OPP outages.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
T&S system uptime less than expected	Commercial / CO_2 Offtake	Probability: 5 – Highly likely Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination

To mitigate this risk, the design of the T&S system was developed to include some redundancy for key equipment (e.g. number of wells, pumps, dual power supplies to the onshore pumping station for higher resilience etc.) that allowed for maintenance to be carried out without shutting down the whole system. This recognised that collaboration to align maintenance work, whilst beneficial, becomes more difficult as more CO_2 emitters join the transport and storage system. During FEED a detailed Reliability and Maintainability (RAM) study was also carried out to demonstrate that the design could meet the required uptime under normal operation.

Further work to ensure coordination of maintenance planning and to work out detailed arrangements for managing outages was planned to be developed during the next project phase.

33. Location of offshore wind turbines impacts subsurface monitoring

The location of offshore wind turbines, for example near Hornsea, was recognised as potentially causing problems with subsurface monitoring.

Firstly, the background noise caused by the turbines could interfere with micro-seismic monitoring, a technique using highly sensitive instruments to detect mini-seismic events in the vicinity of the formation. Although it was not clear whether micro-seismic monitoring would be required given other monitoring techniques that could be used, if the data from this would have been required to satisfy regulatory bodies there was a risk that this may cause issues around the reliability of monitoring.

Secondly, it was identified that offshore wind turbines could also cause problems with seismic monitoring, making it difficult to update seismic surveys in the future. Although alternative monitoring techniques were possible, a lack of reliable seismic data might have caused issues with the regulator.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Location of offshore wind turbines impacts	Commercial / CO_2 Offtake	Probability: 4 - Probable Impact: 4- Very High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
subsurface monitoring				possible at the point of FEED termination

To mitigate this risk, NGC engaged with relevant industry contractors to establish suitable monitoring techniques and determine the sensitivity of the micro-seismic monitoring technique to extraneous noise. A wind farm noise study to assess extent of impact on seismic signal quality and repeatability was also undertaken. Based upon the work performed, it was concluded that the noise spectrum will not cause a problem.

NGC were also engaged with the regulator as part of the Storage Permit Application (which included arrangements for monitoring of the store) at the point of FEED termination.

34. Permit for discharge of formation water

The formation where the CO_2 would have been stored contains saline water and it was foreseen that at a later stage some of this water might need to be discharged. A permit for formation water discharge was not yet in place and there was a risk it may not be granted due to water composition. This might have led to a revision to the project scope as produced water would have needed to be brought to the platform for discharge/ treatment which could have restricted further utilisation of the system.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Permit for discharge of formation water	Commercial / CO_2 Offtake	Probability: 3 – Possible Impact: 5 – Critical	Probability: 2 - Unlikely Impact: 4 – Very High	Partially effective; full assessment not possible at the point of FEED termination

Subsurface modelling work confirmed that the White Rose development did not require water discharge, and this would only be necessary in the future with additional users, at higher CO_2 injection rates. During FEED, analysis of the formation water was undertaken based on samples taken during the appraisal, and risk assessment and dispersion modelling carried out. There was also a consultation with the regulator, and at the point of FEED termination this issue was not envisaged to be a problem.

35. Rig and / or Specialist vessel market volatility

Offshore construction of the pipeline, jacket and topsides, and wells required specialist vessels that were commonly used within the offshore oil and gas industry. These included vessels to lay the pipeline, transport and install the offshore platform jacket and topsides, and drilling rigs for the wells. As there were relatively few of certain types of vessel and they could be deployed globally, the market could be volatile which made it difficult to gain certainty over their price in the future. There was therefore a risk that the cost of carrying out well work in subsequent years, turns out to be higher than budgeted.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Rig and / or Specialist vessel market volatility	Commercial / CO_2 Offtake	Probability: 4 - Probable Impact: 2 - Medium	Probability: 4 - Probable Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination

To mitigate this risk NGC developed a detailed specification of the T&S system during FEED which determined the construction requirements, and also engaged with the supply chain to better understand the market and the variable cost elements. It was also intended to award contracts at the earliest possible opportunity and establish early look-ahead for later rig hire. A residual risk would however have remained as volatility could not be fully mitigated and discussions were ongoing with the Authority to agree suitable adjustment mechanisms.

36. Failure of historical well seals

There were two existing wells in the crest of the store formation which were drilled as part of oil and gas exploration. These were left appropriately plugged and abandoned with multiple barriers between the formation and the seabed surface. There was a risk that the regulator might require a workover of these wells during subsequent stages of the project, to reduce the chances of CO_2 leakage from them, increasing project costs and potentially causing delay.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Failure of historical well seals	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 4 – Very High	Probability: 2 - Unlikely Impact: 4 – Very High	Partially effective; full assessment not possible at the point of FEED termination

To mitigate this risk, considerable work was undertaken to understand the existing wells and the options for workover. The exact location of the wells was confirmed from seabed survey and a detailed assessment of existing wells undertaken, to assist in selection of the injection site. Conceptual re-entry options for the wells had also been assessed as part of the selection of a suitable site.

Further study work considered connection and re-abandonment in accordance with latest standards and requirements for a CO_2 store. It was concluded that re-entry of existing crestal wells was not required as the wells have several seals, such as cement plugs, which form multiple barriers. Additionally the Röt Halite layer would tend to creep into the borehole if residual drilling fluid is lost which would make it very unlikely that seals fail.

This was also a topic being addressed with the regulator and was part of the Storage Permit Application, hence not fully addressed at the time of FEED termination.

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37. Downhole damage caused by contamination from the pipeline

During operations, it was possible that contaminants such as particulates (e.g. corrosion products) could be carried down the pipeline and into the wells. This might have caused downhole damage to the wells and impaired CO_2 injection, potentially requiring a workover of the wells with increased cost implications.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Downhole damage caused by contamination from the pipeline	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2- Unlikely Impact: 3 - High	Effective

The specification of CO_2 allowed into the T&S system had been developed to minimise the chances of corrosion occurring. Fine filters at the platform had also been specified in the FEED design to catch any particulates, to further reduce the likelihood that pipeline contamination causes downhole damage. The storage site operator would have also required the transport system to shut down CO_2 flow should issues have been detected.

38. Injection of CO_2 damages the reservoir cap-rock

The cap-rock is the layer of rock that traps the CO_2 within the storage formation. There was a risk that injection of CO_2 into the reservoir could cause hydraulic fracturing, damaging the cap rock if it was weaker in some areas. Although this would not necessarily lead to CO_2 escaping from the store, it could lead to the project operations getting curtailed.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Injection of CO_2 damages the reservoir cap-rock	Commercial / CO_2 Offtake	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective

The appraisal well data and sub-surface work during FEED greatly increased the understanding of, and confidence in the cap-rock. Hydraulic testing to verify the mechanical strength of the cap-rock was completed. Appraisal well data provided cap rock strength and information to determine injection well location. A full assessment of sub-surface risks was also conducted by industry specialists to understand and mitigate the reservoir related risks.

The data to date suggests cap-rock damage was a very unlikely scenario under reasonable injection pressure scenarios. The injection pressure in the future could be limited by taking a conservative approach to avoid any potential of cap-rock damage.

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39. Risk to safety of personnel from unintentional CO_2 release

During the operation of the T&S system, some maintenance carried out by personnel on location at onshore and offshore facilities would have been necessary. If there was an unintentional release of CO_2 when personnel were present it might have caused harm to them. Additionally, an uncontrolled release of CO_2 on the offshore platform could have also caused a loss of power to attending vessels.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Risk to safety of personnel from unintentional CO_2 release	Commercial / CO_2 Offtake	Probability: 1 – Rare Impact: 5 – Critical	Probability: 1 – Rare Impact: 5 – Critical	Partially effective; full assessment not possible at the point of FEED termination

This risk has been mitigated through appropriate engineering design during FEED to prevent and detect releases taking account of safety assessments that have been carried out. NGC undertook a Site Location and Layout Study during FEED to ensure that any intentional/unintentional CO_2 releases onsite would be safe at the boundary of the site. Any maintenance activities carried out would be to company procedures and processes to ensure that unintentional releases do not occur.

The offshore design includes a temporary refuge for personnel on board the platform, which would have prevented CO_2 ingress and also provided a source of breathable air.

During the next stage of the project, specific operating procedures and maintenance manuals, and work control systems, were planned to be developed. Emergency Response procedures for CO_2 releases (including those for attending vessels) were also planned to be prepared. Finally, Operations and Maintenance personnel would have been suitably trained, and provided with appropriate personal protective equipment.

40. Leakage of CO_2 through reservoir primary / secondary seals from cap-rock permeability

The cap-rock is the layer of rock that traps the CO_2 within the storage formation. There was a risk that CO_2 could leak through reservoir primary seal due to cap-rock permeability. The capacity to inject and hold CO_2 in the target formation would have been adversely impacted.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Leakage of CO_2 through reservoir primary / secondary seals from cap-rock permeability	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 5 - Critical	Probability: 1 - Rare Impact: 1 - Low	Effective

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This risk has been effectively mitigated by the comprehensive appraisal well work and subsequent subsurface work programme. The appraisal well had recovered core in Rot Halite and Rot Shale layers, and a testing programme completed to determine cap rock characteristics. The chosen formation and location has multiple sealing layers which would retain CO_2. Geo-mechanical studies have also been conducted to determine stability of the cap-rock when exposed to CO_2.

41. Reservoir compartmentalisation

If the formation to be used for CO_2 storage was found to be compartmentalised during operations, extra wells would be required to achieve the desired level of CO_2 injectivity. This compartmentalisation could be caused by faulting or cementation within the formation.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Reservoir compartmentalisation	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective

This risk has been effectively mitigated by the comprehensive appraisal work and the following detailed subsurface work programme which included characterisation of the formation. 3D seismic appraisal of the wider area indicated no major faulting of the reservoir. The appraisal well showed no compartments, and well testing investigated a radius of ca. 1km from the wellbore. This work had increased confidence in the absence of compartmentalisation.

42. Adverse weather causes delay during construction

Adverse weather during offshore construction work might have caused delay to some of the activities which rely on high cost specialist vessels, such as pipe laying or installing the jacket and topsides. Although an allowance for weather delay was included in the schedule, there was a risk that this would be exceeded leading to potential project delay and increased costs.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Adverse weather causes delay during construction	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 2 – Medium	Probability: 2 - Unlikely Impact: 2 - Medium	Effective

As part of FEED work, this risk has been mitigated by identifying and prioritising technically challenging installation sections. The programming of these works, such as offshore pipeline construction works, was during the lower weather risk periods (e.g. summer months.).

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Surveys of the platform location, pipeline route and shore approach had been completed to highlight key technical features. This was also under discussion with the supply chain to ensure the risk was appropriately defined and owned.

43. Lack of Operational and Maintenance Experience

Although there is a lot of oil, gas and process, operational and maintenance experience available within the UK and internationally, the same is not true for CO_2 T&S, especially offshore. This might have led to a long learning curve in early operations and potentially poor initial operational performance.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Lack of Operational and Maintenance Experience	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 2 - Medium	Probability: 2 - Unlikely Impact: 2 - Medium	Effective

The importance of planning well in advance of commencing operations to address this risk was recognised. Although more detail would have been developed in the next stage of the project, an operations resourcing and training plan, as part of the overall Operations and Maintenance Philosophy was developed within FEED. This would have ensured early recruitment and training for operations and maintenance crews.

As part of detailed engineering during the construction phase, Operations and Maintenance standards procedures were planned to be developed, including training and documentation from EPC contractors for installed equipment. Additionally, a critical analysis of all spares would have been carried out prior to start up so that there was an appropriate amount of operational spares provided by the EPC contractors.

44. New construction specifications required for CO_2 pipelines

There was a risk that new construction specifications in relation to the design of the pipeline which were unique to transport or compression of CO_2 could be introduced prior to the start of operations causing project delay (from revision of the design and development of standards).

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
New construction specifications required for CO_2 pipelines	Commercial / CO_2 Offtake	Probability: 1 - Rare Impact: 1 - Low	Probability: 1 - Rare Impact: 1 - Low	Effective

To mitigate this risk NGC carried out an appraisal of relevant construction specifications already in place. Early entrants into CCS operations were also addressing this issue concurrently. The conclusion was that the design would use standard pipe according to existing code, and this risk was ultimately not considered as a credible issue for design.

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The FEED design has produced a specification to enable pipeline construction.

45. Temporary instability at start of CO_2 injection

At the start of CO_2 injection it was possible that there might be flow instability and transient effects at the well. This could have led to vibration of well components and the risk of their failure. If this occurred the affected wells would have needed to be shut-down and repaired leading to additional costs and impacting the full-chain operational availability.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Temporary instability at start of CO_2 injection	Commercial / CO_2 Offtake	Probability: 5 – Highly Likely Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Effective

During FEED this potential issue was studied and analysed to increase understanding of the flow regime and transient effects. Initial dynamic flow assurance was completed, showing minimal phase change issues in the wellhead. Further transient state flow assurance modelling was also undertaken.

Further work would have been carried out to address this in the next stage of the project, such as the development of the well design and operating procedures to manage any instability. Further flow assurance work would also have been carried out as is normal practice as part of the detailed engineering design.

46. Major archaeological find along pipeline route

Given the existence of archaeology throughout the UK, it was possible that a major archaeological find may be located along the pipeline route. This might have led to a delay to pipeline construction whilst suitable investigations and excavations were undertaken.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Major archaeological find along pipeline route	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination

This risk has been reduced through the pipeline route selection and survey work to date. A programme of archaeological works had been planned in the first two years along the pipeline route and had been reflected in the Project Programme. This programme together with the planned overall construction float would have reduced the risk score at the point of FEED completion.

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47. Decommissioning costs

The project's economic model would have been largely fixed at the time of the project entering into a CfD. This would have also fixed a limit on project decommissioning costs substantially in advance of when the costs would have been incurred. The risk was further compounded by an absence of suitable published data from recent decommissioning of large stations. A deviation (higher actual costs) from assumptions included in the model would have invariably impacted shareholder returns.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Decommissioning costs	Financial	Probability: 3 - Possible Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination

The project was seeking feedback from stakeholders and advisors to attempt to validate initial cost assumptions. At the same time, a regular landscape scan was being performed for data that might become available including from other industries. Ultimately, if suitable benchmark data would not have been found, a contingency provision in the model might have been required.

48. Milestone verification regime

The project intended to follow a milestone completion based project progress verification and payment regime for key contracts / agreements such as construction EPC contracts, financing agreements, funding contract with the Authority etc. As compared to conventional project financed projects, the Authority was an additional key stakeholder in this project. There was a risk that the Authority and the financing institutions employ different entities for certifying completion of construction milestones and these disagree with each other blocking release of construction finance.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Milestone verification regime	Financial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination

The project was pursuing building a consensus to enable appointment of a sole certifying body agreeable to all parties. The selected entity would have had a duty of care towards the Authority as well as towards the financing institutions.

49. Documentation completion milestones

It was expected that certain key documentation would constitute progress milestones for disbursement of funding under the Project Contract with the Authority. There was a risk that a delay in approval of such documents could lead to a financing shortfall and undue pressure on contingent equity and the available

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working capital. There was also a risk that subject to the finally agreed regime, a retention is applied by the Authority to funding disbursement on account of non-acceptance of certain documents.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Documentation completion milestones	Financial	Probability: 4 - Probable Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination

The project was seeking to accurately define and agree milestones with a clear completion criterion making an assessment easier for all stakeholders. The project was also discussing alternative means of project assurance rather than the use of cash retention.

50. Insurance coverage

Considering the commercialisation nature of the project, availability of full insurance coverage as necessary for the construction and/or operation of the full-chain project could not have been assumed. Any lack of insurance products or gaps in insurance coverage might have made continued construction and/or operation unviable and/or impact project economics.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Insurance coverage	Financial	Probability: 3 - Possible Impact: 5 - Critical	Probability: 3 - Possible Impact: 5 - Critical	Assessment not possible at the point of FEED termination

As a first step the project's insurance advisors conducted a market engagement exercise to gauge market interest and availability of suitably worded insurances. Subsequently regular assessments were being conducted to assess positive or negative changes to initial assumptions. Discussions with the Authority were ongoing to assess potential impacts and develop mechanisms to address changes in insurance coverage in the construction and operational phases. These were not limited to changes originating from events tied to the project.

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5 FEED activities risk management

The project team maintained a central FEED risk register compiling key risks to the FEED. This register was an important FEED management tool and was regularly reviewed and updated. For clarity the FEED risk register did not include risks to the project phases beyond FEED (e.g., construction) but was focused at risks to FEED activities.

Included here is a brief description of twenty-five key risks from the FEED risk register. For each risk the following details have been provided:

- Background and risk description
- Risk category
- Risk score when the risk was identified
- Mitigation plan
- Mitigation effectiveness assessment

Mitigation effectiveness assessment has been subjectively performed and the following effectiveness categories have been used in this report:

- **Effective** used where the deployed mitigation strategy has been assessed to be successful.
- **Partially effective** used where the deployed mitigation strategy has been assessed to be partially successful.
- **Assessment not possible at the point of FEED termination** used where an assessment on effectiveness was not possible at the point of FEED termination.
- **Partially effective; full assessment not possible at the point of FEED termination**: this category flows from the previous bullet but has been used for a sub-set of risks where though a complete assessment was not feasible, a partial success was clearly visible.
- **Not effective**: used where the deployed mitigation strategy has been assessed to be not successful.

The following probability and impact scoring approach was deployed for the FEED risk register:

Table 5.1: Impact scoring approach for the FEED risk register

Score	Meaning	Cost	Schedule
5	Critical	> £3m	> 12 weeks
4	Very high	> £1m - £3m	> 8 – 12 weeks
3	High	> £300k - £1m	> 4 – 8 weeks
2	Medium	> £100k - £300k	> 2 – 4 weeks
1	Low	> 0 - £100k	> 0 – 2 weeks

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Table 5.2: Probability scoring approach for the FEED risk register

Score	Meaning	Probability
5	Highly likely	> 75%
4	Probable	> 40% - 75%
3	Possible	> 15% - 40%
2	Unlikely	> 5% - 15%
2	Rare	> 0 – 5%

The risk assessments compiled below also use the above scoring approach.

1. FEED scope adequacy

FEED was largely scoped, budgeted and set-up before the commencement of the FEED Contract with the Authority. FEED and the contained development activities due to their nature might have necessitated performance of additional work to resolve issues and mitigate risks as they are identified and assessed. There was a risk that the FEED scope as established at the beginning may not be sufficient to meet the FEED objectives, a key requirement of the FEED Contract with the Authority.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
FEED scope adequacy	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Effective

This risk was already identified and considered for FEED planning performed during the pre-FEED phase. The team was again made familiar with this risk at the FEED kick-off workshop through an open discussion on this topic. Subsequently, there was a regular interrogation of scope and activities as FEED progressed with the need for potential modifications discussed at appropriate forums. Looking forwards tests were also conducted to minimise the possibility of downstream activities requiring completed work to be reopened again, e.g., an assessment of technical definition work that potential funders may require was performed early using CPL's advisors. These mitigation strategies were quite effective in minimising the need to modify FEED scope. However, for some of the identified necessary changes, performance was delayed as details were discussed with the Authority.

2. Project commercial and risk structuring appropriateness for financing

The OPP part of the project was being developed for project financing and there was a risk that potential funders do not agree with the proposed project commercial structuring and risk allocation.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Project commercial and risk structuring appropriateness for financing	Commercial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination

To mitigate the risk, CPL helped by its financial advisor regularly applied look forwards tests on the structuring as it was developed based upon feedback and precedents available from other project financed projects. This also involved CPL's advisors acting as 'Shadow lenders' advisors'. Structured feedback was also sought directly and independently from certain 'Pathfinder banks' and lenders' advisors. Lastly, CPL intended to follow classical project financing processes to develop OPP financing.

3. Management of state-aid clearance programme

The Authority's support to the project and the effectiveness of the Project Contract with the Authority and the CfD with the Low Carbon Contracts Company was conditional upon the Authority obtaining necessary state-aid clearance from the European Commission. There was a risk that the state-aid clearance gets delayed, is conditional or is challenged in the courts. Any one of these could have potentially impacted the project as the contracts mentioned above as well as other contracts and agreements such as construction contracts and financing agreements were required to be prepared before submission of state-aid clearance notification and would have been expected to be conditional on clearance.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Management of state-aid clearance programme	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

Management of state-aid clearance was an Authority process. CPL maintained a dialogue with the Authority and other stakeholders on this issue as the FEED progressed. Considering the correlation between the state-aid clearance timeline and the FEED critical path, potential actions were to be provided highest priority by the CPL team.

4. Debt markets liquidity levels

Considering the FEED structuring and duration, there was a risk that debt market liquid levels might be inadequate when the project solicits formal financing proposals from financing institutions.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Debt markets liquidity levels	Commercial	Probability: 2 - Unlikely Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 4 – Very high	Effective

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Obtaining regular market feedback from CPL's financial advisor was an integral part of the financing work-stream. CPL also maintained a regular dialogue with potential financing institutions through the FEED which together with targeted broadening of the funder group was effective in mitigating this risk up until the point of FEED termination.

5. Grid connection liability

Applying for and securing grid connection is a defined and regulated process in the UK. As per this process, entering into a grid connection agreement during FEED (determined by lead times) and then not being able to achieve a financial close might have left the project liable for cancellation charges.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Grid connection liability	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - Medium	Effective

The mitigation plan involved maintaining a close dialogue with National Grid Electricity Transmission (NGET) on project progress as well as on the grid connection development plan. The teams assessed the connection options and the minimum work that was necessary to ensure sufficient progress on the grid connection. The grid connection agreement also contained mechanisms to identify milestones which led to an increase in project liability. These measures ensured that the project's cancellation charge liability was zero at the point of FEED termination.

6. Electricity market reform (EMR) progress

The project's proposed structuring drew upon elements of the broader GB electricity market reform. There was a risk, more acute during the initial months of FEED, that a delay in EMR progress could slow or stall negotiation / finalisation of the Project Contract and the CfD.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
EMR progress	Commercial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High	Effective

The CPL team and CPL's advisors closely followed progress of EMR (as well as of the associated market) directly as well as through the Authority's team. New information or mechanisms as they became available were assessed as a part of FEED work. The draft Project Contract and CfD when they were made available also clarified the contractual underpins proposed for the project further mitigating the risk.

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7. FEED timeline delay

White Rose was a CCS commercialisation project and due to its nature, the project involved putting in place structures and mechanisms that were unique and not readily transferable from other projects and markets without significant adjustments. There was a risk that commercial negotiations to agree these details with the Authority, market-test the agreed novel structures with the financing institutions and with the supply chain and finally align project implementation contracts and agreements appropriately required more time than that which was assumed for FEED planning.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Delay in FEED timeline arising from a delay in commercial negotiations completion	Commercial	Probability: 4 - Probable Impact: 3 – High	Probability: 4 - Probable Impact: 3 – High	Not effective

The project team engaged with the Authority early in FEED to obtain clarity on the expected process as well as key milestones supporting a timely completion of FEED. A kick-off workshop involving the project team and the Authority team was also held early in FEED to discuss the process, review baseline positions and agree a way forward. As a part of this engagement, the project team also sought commercial discussions and agreements at principles level upfront of negotiation of detailed contractual drafts. Structured market-testing was added to the programme to support progress of commercial work-streams. Finally, commercial negotiations as well as formal reporting to the Authority under the FEED programme also included a periodic review of project progress.

8. First-time permitting of a CCS power plant

White Rose OPP would have been the first CCS power plant and the first supercritical thermal power station to be permitted in the U.K. There was a risk that the relatively new Development Consent Order (DCO) process when applied to the new station might lead to out of plan modifications, need for rework, consenting delay etc.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
First-time permitting of a CCS power plant in England.	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Partially effective

The mitigation planned involved engaging proactively with the authorities and other stakeholders throughout the DCO process to anticipate likely issues and resolve them in advance of formal submissions. Further, the FEED activities and scopes were suitably tailored to be able to support the mitigation plan, e.g., through preparation of specific customised documentation. Implementation of this strategy also

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reduced unexpected feedback from key stakeholders late in the process. Through the FEED execution plan it was ensured that the CPL team as well as FEED sub-contractors recognised and understood the permitting work-flow and process.

9. OPP Development Consent Order (DCO) process

Preparation of a Preliminary Environmental Information Report (PEIR) for the OPP and consultation with stakeholders based upon the prepared report is a key part of the DCO process. Considering the development programme and the timeline laid for the DCO process, PEIR consultation happened relatively early in the development phase. There was a risk that a post PEIR change in project design, however minor, might be picked up by a consultee and in an unlikely worst case require restart of the PEIR process.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Management of the PEIR within the DCO process	Permitting	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 – Critical (Risk closed)	Effective

As with the previous risk, this risk was also mitigated through a mix of proactive engagement with stakeholders, alignment of design development FEED work with DCO timing and overall detailed planning within the FEED execution plan. CPL also ensured that only experienced consultants with the right expertise worked on DCO development. The team also continuously looked for potential learnings from initial projects that had just started to complete their DCOs.

10. OPP applicable noise limit

There was a risk that the project was unable to agree applicable operational noise limits with the relevant authorities necessitating rework, leading to a Capex increase and potentially being difficult to achieve. This was further compounded by the fact that noise limits are reviewed under both the DCO and under the environmental permit potentially leading to conflicting requirements.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Agreement of applicable noise limits.	Permitting	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

Minimising noise impact was identified as a key objective for FEED design. Driven by this objective and supported by a clear basis of design, emphasis was laid on appropriate equipment selection, layout development and on other mitigation measures such as use of appropriate enclosures. Sensitive receptors were identified during FEED and assessed as a part of design development. A consultation with the local authority was also conducted ahead of the PEIR exercise to agree applicable limits using relevant

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standards. During the PEIR exercise and as a part of feedback received, the design was again adjusted to meet the set limits. It was also ensured that the same team worked on DCO development and environmental review to ensure consistency. Late in the DCO process there was disagreement with a relevant authority on what had been considered as the applicable limit. CPL prepared additional information to support its case and the issue was with the examining authority for a final decision at the time of FEED termination.

11. CO_2 safety case

The Health & Safety Executive (HSE) currently has no authority to deal with CO_2 as a hazardous fluid (the project included the first dense phase CO_2 pipeline in England). There was a risk that this may change at some point in the future and HSE may require additional technical work, over and above what has been planned, to be performed late in FEED.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 safety case	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Effective

The primary mitigation strategy was to continue to treat CO_2 as a hazardous fluid from the outset irrespective of the scope of HSE responsibilities. Further, HSE was contacted early in FEED and a dialogue maintained updating them of the proposed approach.

12. Storage permit delay

A CO_2 storage permit for an offshore saline formation would have been granted for the first time in the UK. There was a risk that the process of reviewing the application and the granting of the permit by the competent UK permitting authority would take longer than expected to the extent that it could delay completion of the project FEED.

The permit application was more complex than that required for hydrocarbon extraction, comprising a detailed desk-based geological site characterisation which evaluates primary and secondary containment options, static storage capacity estimates and seal integrities. Other components of the permit related to the management of residual risks and included the storage monitoring plan, together with consideration of contingency and corrective measures and the post-closure plan. It was also recognised that permitting authority organisational changes and other commitments could hinder the review of the permit application.

Further, the granting of the permit also depended on other statutory bodies. Although the UK permitting authority would have accepted the draft application when satisfied that it met their requirements, from this point (draft acceptance), the application and associated draft permit would have been reviewed by the European Commission over a four month period. The UK permitting authority must consider this opinion ahead of awarding the Permit. Lastly, prior to award of the Permit, the applicant must have an Environmental Statement accepted by Department of Energy and Climate Change (DECC), UK. To obtain

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acceptance of the ES the applicant must address any issues or concerns raised by DECC following the completion of the statutory public consultation.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Delay to the granting of the storage permit	Permitting	Probability: 2 - Unlikely Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 4 – Very high	Assessment not possible at the point of FEED termination

Considering the lack of precedence, the project team engaged upfront with the competent authority to agree the review process (within the guidance available) including the interface to the European Commission. Even though this led to a delay in storage permit activities as compared to FEED planning basis (prepared based upon guidance available), the engagement reduced uncertainty and the expected delay could be managed. At project termination, NGCL were in the process of submitting the Storage Permit application.

13. Technical rework arising from the storage permit application review

A CO_2 storage permit for an offshore saline formation would have been granted for the first time in the UK. There was a risk that the permitting authority would require significant rework of the application package as well as other underlying work when reviewing the application.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Technical rework arising from the storage permit application review	Permitting	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective

Considering the lack of precedents, the project team engaged upfront with the competent authority to agree the review process (within the guidance available). This engagement also clarified / confirmed the extent of underlying technical work necessary as well as documentation to be included in the application which reduced uncertainty.

14. CO_2 flow-metering concept

A full-chain CO_2 flow metering concept was being developed for the project based upon applicable regulations and guidelines. The developed concept did not foresee statutory or tariff metering being conducted offshore at the platform. There was however a risk that despite the robustness of the proposed concept, an offshore high accuracy metering is required by the permitting authority or the Authority. Such a decision would have had necessitated a FEED rework together with a significant economic impact on the project.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 flow-metering concept	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination

The mitigation plan was primarily based upon upfront engagement with the appropriate authority backed by a robust plan that addresses all requirements without the need for offshore statutory metering. The storage permit application was being prepared based upon the initial understanding from this engagement.

15. CCS chain technical integration

White Rose was a full-chain CCS project and a significant part of the development effort focussed on ensuring that the full-chain consisting of the OPP, CO_2 transport infrastructure and CO_2 storage infrastructure is technically integrated. The OPP was planned to be project financed and the financing institutions were catching-up with CCS technology through efforts made on the project and otherwise. There was however a risk that the project fails to convince potential lenders that the CCS chain is technically full integrated which might have made financing difficult.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CCS chain technical integration	Technical	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

The objective of achieving full-chain technical integration was embedded in the overall FEED execution plan. This was ensured through agreeing a full-chain basis of design as well as through an early development of full-chain philosophies (commissioning, operation and maintenance, RAM, control etc.) to guide detailed technical work. Establishing these philosophies brought together key stakeholders and there was a broad buy-in. As FEED progressed, all activities with respect to full-chain integration were closely monitored and interrogated. The project also revisited these philosophies at FEED end to confirm that the objectives have been suitably achieved. Further, the project's market engagement with the financing institutions invariably involved sufficient focus on technical aspects including full-chain alignment. Lastly, the project team proactively decided to bring forward, detailed technology due-diligence to be performed by Lenders' Technical Advisor (LTA) to ensure that there was sufficient time available to clarify any concerns raised and act upon feedback received.

16. Broad agreement on CCS related risks

The CCS Commercialisation Programme foresaw sharing of certain CCS related risks between the Authority and the industry with the objective of facilitating commercialisation of the technology. This was intended to be formalised through appropriate provisions in the Project Contract. There was however a risk

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that achieving an agreement on what precisely constitutes CCS risks takes longer than anticipated. The stakeholders involved in this process included the project teams, the Authority, financing institutions as well as parts of project supply chain.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Broad agreement on CCS related risks	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

The project conducted a bottom-up assessment of what constitutes CCS risk facilitated by an initial guiding definition. This list was also presented to the Authority in a workshop before commencing detailed discussions on provisions of the Project Contract. The assessment included an engagement with other stakeholders, where appropriate. A proposal based upon this engagement and feedback was then prepared by the project team and was awaiting presentation to the Authority at the point of FEED termination.

17. Offshore infrastructure routing / layout

Numerous oil & gas and offshore wind projects are located in the North Sea. There was a risk that the routing of the pipeline and/or siting of offshore infrastructure results in adverse impacts on third parties leading to objection and/or delays to the project.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Offshore infrastructure routing / layout	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 – High (Risk closed)	Effective

The risk was mitigated through a combination of comprehensive surveying and environmental impact assessment, allowances for crossings in the design and negotiation of crossing agreements. As an enabling action, all affected parties were identified and a close relationship maintained as FEED progressed.

18. Full-chain basis of design evolution

A full-chain basis of design document was established at FEED start to facilitate and align FEED work. There was however a risk that this document might need to be modified as FEED progressed impacting fundamental assumptions upon which other work has been carried out, thereby rendering parts of performed work redundant.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain basis of design evolution	Technical	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 - High	Effective

The risk was largely mitigated through scheduling preparation of full-chain philosophies early in FEED as the potential for an impact was largest from these philosophies. A robust change management process deployed for FEED also ensured that changes where necessary were controlled appropriately. The full chain basis of design was updated and re-issued to reflect the changes identified and implemented in FEED.

19. Use of Best Available Technology (BAT) for the OPP

The design of an OPP differs in many aspects from a conventional air-fired station, e.g., on the sizing of air quality control systems. There was a risk that permitting authorities consider the proposed plant design to not represent BAT and that re-engineering is required.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Use of Best Available Technology (BAT) for the power plant	Technical	Probability: 2 - Unlikely Impact: 3 - High	Probability: 1 - Rare Impact: 3 – High (Risk closed)	Effective

Design of relevant components and systems was interrogated from a BAT perspective and updated as necessary. An overall BAT assessment was also performed and the end report submitted as part of DCO documentation.

Discussions were had with the EA on their draft BAT guidelines in order to ensure acceptance of the OPP design.

20. Grid code compliance

All existing coal stations connected to the UK grid, due to their age and the technology are of a sub-critical design and largely comply with the grid code requirements. There was a risk that the OPP which, is not only of a higher efficiency supercritical design but also incorporates plants and systems not seen on older stations, and additionally incorporates full-chain CCS, might not fully comply with the as drafted grid-code requirements. There was also a risk that local network conditions might impose undue constraints on operating characteristics.

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Grid code compliance	Technical	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

This risk was mitigated through an early assessment of grid-code requirements so that FEED could be scoped appropriately. FEED work therefore included simulations of plant characteristics significant for the grid code assessment. Engagement with NGET was initiated early in the FEED to understand requirements, local grid characteristics as well as discuss results from simulations. For all engagement sessions CPL was supported by experts with a good understanding of local network as well as UK and European grid requirements. Whilst the project was satisfied that most grid code requirements had been or could be satisfied, at the time of FEED termination work remained on fault ride though capabilities, some of which may not have been met against assumed (pessimistic) background conditions. Work was on-going regarding more appropriate background conditions as well as the imminent inclusion of European Grid Code requirements which might have been easier to fulfil.

21. Supply-chain competitiveness

Considering the evolving market conditions and the project timeline (gap between point of tendering and order placement) there was a risk of non-availability of competitive firm pricing proposals from the project supply chain.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Supply-chain competitiveness	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination

Mitigation of this risk was planned through an effective communications plan for all stakeholders including an alignment with the Authority on communication of the project's significance. The project supply chain was made aware of the project timeline when the tendering effort was launched.

22. CO_2 well design

There was a risk that design of wells might necessitate the move to non-standard exotic material for injection tubing and/or a need for a review of CO_2 specifications.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
CO_2 well design	Technical	Probability: 5 – Highly likely	Probability: 3 - Possible	Effective

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
		Impact: 3 - High	Impact: 3 – High	

As this issue was being reviewed and assessed, the underlying design work was progressed based upon best practices for standard oilfield equipment. This also included a literature review of latest developments and R&D for CO_2 wells and water producers. To further mitigate the risk the required CO_2 specifications were reviewed again and an assurance programme undertaken on the OPP design and off-specification CO_2 protection concept. A comparative lifecycle cost review covering the full-CCS chain was also undertaken for various CO_2 specifications requirement with the objective of securing a competitive and economic solution. Other back-up strategies around laboratory testing of material etc. though initially contemplated could be dropped and it was concluded that non-standard exotic materials will not be required. Wells design was based on Super-duplex Stainless Steel or similar material.

23. Full-chain integration management process

There was a risk that the project team and FEED sub-contractors spend too much time trying to agree full-chain philosophies at FEED start, effectively reducing the time available for design development and permitting documentation development right from launch of FEED work.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Full-chain integration management process	Management process	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Effective

This risk was eliminated through establishment and following-up of a detailed plan for defining and agreeing full-chain philosophies. All sessions and activities were planned in detail to ensure appropriate participation and that objectives, deliverables and dependencies were clearly understood and all actions followed-up in a timely manner. The exercise involved bringing together project teams and supply-chain representatives from across the full-chain and was concluded in an effective and efficient manner.

24. Further appraisal well needed to achieve consent

There was a risk that a further appraisal well was required to provide data to consent the storage site if there was inadequate or insufficient data to satisfy the regulator. This would have led to a failure to obtain a Storage Permit in the timescale expected, an increase in project costs and a project delay.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Further Appraisal Well required to	Technical	Probability: 2 - Unlikely Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective

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Risk title	Category	Score when identified	Current score	Mitigation effectiveness
provide adequate data to consent the storage site.				

The risk was managed by ensuring the initial appraisal program was well defined so that sufficient data would be gathered to allow injection well design and location to be specified. There was also engagement with the regulator to develop confidence in the appraisal results and the field model to allow permitting. Although consent was not achieved at the point of FEED termination, the Appraisal Well programme had provided comprehensive and positive results.

25. Further full scale testing needed, delaying pipeline design parameter confirmation

There was a risk of a delay to the confirmation of pipeline design parameters, as investigation of the potential for failure mechanism during pipeline design required additional testing. This research might have resulted in changes to the assumed material specifications, leading to rework and a delay to the FEED schedule.

Risk title	Category	Score when identified	Current score	Mitigation effectiveness
Delay in confirmation of pipeline design parameters	Design	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective

Data from NGC's extensive R&D programme funded by the European Commission enabled NGC to confirm the approach to fracture control and therefore ensured that the pipeline design included suitable pipe thickness to restrict the propagation of any failure.

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Appendices

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Appendix A Key project risks compilation

Table A.1: Key project risks

#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
1	Full-chain engineering activities	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
2	Full-chain operating practices and procedures	Project management	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
3	Management of engineering interdependencies between the OPP and T&S system	Project management	Probability: 3 - Possible Impact: 3 -High	Probability: 3 - Possible Impact: 2 - Medium	Effective
4	Management of construction interdependencies between the OPP and T&S systems	Project management	Probability: 3 - Possible Impact: 3 -High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective
5	Grid connection delay	Project management	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
6	Project knowledge management	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 – Unlikely Impact: 3 - High	Effective
7	Management of Authority deliverables	Project management	Probability: 3 - Possible Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination
8	Contract management	Project management	Probability: 3 - Possible Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination
9	Labour discontent and strikes	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Assessment not possible at the point of FEED termination
10	Availability of skilled labour	Project management	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination
11	Project protestors causing disruption to project site	Corporate, Legal & Political	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
12	Introduction of new guidelines and standards for CCS	Corporate, Legal & Political	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination

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#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
13	Archaeological findings in the OPP laydown area	Environmental & Permitting	Probability: 3 - Possible Impact: 2 - Medium	Probability: 1 - Rare Impact: 2 - Medium	Effective
14	EMR – EPS requirements	Environmental & Permitting	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
15	Detailed design within DCO boundary limits	Environmental & Permitting	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination
16	OPP technical integration	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 1 - Rare Impact: 2 - Medium	Effective
17	Dense phase CO_2 measurement	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective
18	CO_2 T&S system – operating flexibility	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
19	Full-chain maintenance alignment	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
20	Full-chain operation	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
21	OPP site raising delay risk	Technical	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Effective
22	OPP commissioning	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
23	New CDM requirements	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 2 - Medium	Effective
24	OPP plant type	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
25	CO_2 stream specification	Technical	Probability: 3 - Possible Impact: 5 - Critical	Probability: 2 - Unlikely Impact: 3 - High	Effective
26	Overall metering concept	Commercial	Probability: 4 - Probable Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination
27	Full-chain commissioning alignment	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
28	CO_2 T&S infrastructure risks in a multi-user environment	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination

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#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
29	Requirement of mandatory access to T&S system causing delays	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination
30	CfD indexation	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
31	Insufficient demand for CCS results in no follow-on loads after CPL	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination
32	T&S system uptime less than expected	Commercial / CO_2 Offtake	Probability: 5 – Highly likely Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination
33	Location of offshore wind turbines impacts subsurface monitoring	Commercial / CO_2 Offtake	Probability: 4 - Probable Impact: 4- Very High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
34	Permit for discharge of formation water	Commercial / CO_2 Offtake	Probability: 3 – Possible Impact: 5 – Critical	Probability: 2 - Unlikely Impact: 4 – Very High	Partially effective; full assessment not possible at the point of FEED termination
35	Rig and / or Specialist vessel market volatility	Commercial / CO_2 Offtake	Probability: 4 - Probable Impact: 2 - Medium	Probability: 4 - Probable Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination
36	Failure of historical well seals	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 4 – Very High	Probability: 2 - Unlikely Impact: 4 – Very High	Partially effective; full assessment not possible at the point of FEED termination
37	Downhole damage caused by contamination from the pipeline	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2- Unlikely Impact: 3 - High	Effective
38	Injection of CO_2 damages the reservoir cap-rock	Commercial / CO_2 Offtake	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective
39	Risk to safety of personnel from unintentional CO_2 release	Commercial / CO_2 Offtake	Probability: 1 – Rare Impact: 5 – Critical	Probability: 1 – Rare Impact: 5 – Critical	Partially effective; full assessment not possible at the point of FEED termination
40	Leakage of CO_2 through reservoir primary / secondary seals	Commercial / CO_2 Offtake	Probability: 2 - Unlikely Impact: 5 - Critical	Probability: 1 - Rare Impact: 1 - Low	Effective

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#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
	from cap-rock permeability				
41	Reservoir compartmentalisation	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Effective
42	Adverse weather causes delay during construction	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 2 – Medium	Probability: 2 - Unlikely Impact: 2 - Medium	Effective
43	Lack of Operational and Maintenance Experience	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 2 - Medium	Probability: 2 - Unlikely Impact: 2 - Medium	Effective
44	New construction specifications required for CO_2 pipelines	Commercial / CO_2 Offtake	Probability: 1 - Rare Impact: 1 - Low	Probability: 1 - Rare Impact: 1 - Low	Effective
45	Temporary instability at start of CO_2 injection	Commercial / CO_2 Offtake	Probability: 5 – Highly Likely Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Effective
46	Major archaeological find along pipeline route	Commercial / CO_2 Offtake	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 2 - Medium	Partially effective; full assessment not possible at the point of FEED termination
47	Decommissioning costs	Financial	Probability: 3 - Possible Impact: 2 - Medium	Probability: 3 - Possible Impact: 2 - Medium	Assessment not possible at the point of FEED termination
48	Milestone verification regime	Financial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination
49	Documentation completion milestones	Financial	Probability: 4 - Probable Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination
50	Insurance coverage	Financial	Probability: 3 - Possible Impact: 5 - Critical	Probability: 3 - Possible Impact: 5 - Critical	Assessment not possible at the point of FEED termination

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Appendix B Key FEED risks compilation

Table B.1: Key FEED risk

#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
1	FEED scope adequacy	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Effective
2	Project commercial and risk structuring appropriateness for financing	Commercial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination
3	Management of state-aid clearance programme	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
4	Debt markets liquidity levels	Commercial	Probability: 2 - Unlikely Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 4 – Very high	Effective
5	Grid connection liability	Commercial	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - Medium	Effective
6	EMR progress	Commercial	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High	Effective
7	Delay in FEED timeline arising from a delay in commercial negotiations completion	Commercial	Probability: 4 - Probable Impact: 3 – High	Probability: 4 - Probable Impact: 3 – High	Not effective
8	First-time permitting of a CCS power plant in England.	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Partially effective
9	Management of the PEIR within the DCO process	Permitting	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 – Critical (Risk closed)	Effective
10	Agreement of applicable noise limits.	Permitting	Probability: 4 - Probable Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
11	CO_2 safety case	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Effective
12	Delay to the granting of the storage permit	Permitting	Probability: 2 - Unlikely Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 4 – Very high	Assessment not possible at the point of FEED termination
13	Technical rework arising from the storage permit application review	Permitting	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective
14	CO_2 flow-metering concept	Permitting	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 4 – Very high	Assessment not possible at the point of FEED termination

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#	Risk title	Category	Score when identified	Current score	Mitigation effectiveness
15	CCS chain technical integration	Technical	Probability: 3 - Possible Impact: 4 – Very high	Probability: 3 - Possible Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
16	Broad agreement on CCS related risks	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 - High	Assessment not possible at the point of FEED termination
17	Offshore infrastructure routing / layout	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 3 - Possible Impact: 3 – High (Risk closed)	Effective
18	Full-chain basis of design evolution	Technical	Probability: 3 - Possible Impact: 4 – Very high	Probability: 2 - Unlikely Impact: 3 - High	Effective
19	Use of Best Available Technology (BAT) for the power plant	Technical	Probability: 2 - Unlikely Impact: 3 - High	Probability: 1 - Rare Impact: 3 – High (Risk closed)	Effective
20	Grid code compliance	Technical	Probability: 2 - Unlikely Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 - High	Partially effective; full assessment not possible at the point of FEED termination
21	Supply-chain competitiveness	Technical	Probability: 3 - Possible Impact: 3 - High	Probability: 4 - Probable Impact: 3 - High	Assessment not possible at the point of FEED termination
22	CO_2 well design	Technical	Probability: 5 – Highly likely Impact: 3 - High	Probability: 3 - Possible Impact: 3 – High	Effective
23	Full-chain integration management process	Management process	Probability: 3 - Possible Impact: 3 - High	Probability: 2 - Unlikely Impact: 3 – High (Risk closed)	Effective
24	Further Appraisal Well required to provide adequate data to consent the storage site.	Technical	Probability: 2 - Unlikely Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective
25	Delay in confirmation of pipeline design parameters	Design	Probability: 1 - Rare Impact: 5 - Critical	Probability: 1 - Rare Impact: 5 - Critical	Effective

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