## NORTH LONDON WASTE AUTHORITY

**REPORT TITLE:** NORTH LONDON HEAT AND POWER PROJECT – CARBON CAPTURE AND STORAGE UPDATE

**REPORT OF:** PROGRAMME DIRECTOR

**FOR SUBMISSION TO:** PROGRAMME COMMITTEE

**DATE:** 2 SEPTEMBER 2021

**SUMMARY OF REPORT:**

The report provides a summary of the outline Carbon Capture and Storage (CCS) Strategy for the Energy Recovery Facility and describes the high-level activities which will be delivered as part of the forward plan to ensure the Authority is well placed to implement CCS in the future. The outline Strategy, is a live document which will be regularly reviewed and updated as the emerging policy in this area develops over the coming months and years.

**RECOMMENDATIONS:**

The Committee is recommended to comment on and agree the outline strategy set out at Appendix A

**SIGNED:** ............................................ Programme Director

**DATE:** 20 August 2021

## 1. INTRODUCTION

1.1. The purpose of this paper is to provide an overview of the Authority's outline strategy to developing a carbon, capture and storage (CCS) solution for the Energy Recovery Facility (ERF). The Authority's outline CCS contained in Appendix A to this report. A glossary of the terms and abbreviations used is appended to that strategy.

1.2. The outline strategy is a live document which will be regularly reviewed and updated as the emerging policy in this area develops over the coming months and years. There are many challenges to implementing a viable CCS solution for the ERF, both technical and financial. The deployment timeline is dependent on available funding and financing and on establishment of a suitable transport and storage (T&S) network connection for the ERF. Officers will closely monitor these issues and seek to actively engage with key stakeholders in the sector including the Department for Business, Energy and Industrial Strategy (BEIS) to highlight the role of energy from waste in relation to CCS and provide update reports for Members.

1.3. Carbon management is key to achieving our net zero ambitions and the approach in the outline strategy shows how it is planned for the ERF to be one of the first ERFs in the country to be fitted with carbon capture for transport and storage. The outline strategy explains both 'Carbon Capture Use and Storage' (CCUS) as the overarching term to describe carbon capture and 'Carbon Capture and Storage' (CCS) which refers specifically to the permanent underground storage of carbon. The outline strategy provides the reason why it is currently anticipated that CCS will be the preferred route for the management of carbon with regard to the ERF. The explanation and reasoning are summarised in section 2 of this report.

1.4. The ERF will contribute to the Net Zero economy, by diverting waste from landfill and generating low carbon heat and power. The Authority's constituent boroughs do, and will continue to, provide extensive and well performing recycling and composting services. However, there will always be some waste which is not suitable for recycling. For example, materials mixed in with residual waste are typically too contaminated to be repurposed into new products.

1.5. A significant fraction of the incoming waste-based fuel will be of biogenic origin, including paper, cardboard, wood, food waste and garden trimmings. Carbon emissions of biogenic waste are not climate-relevant and are considered 'short cycle' as the carbon dioxide was recently absorbed by growing matter, as opposed to fossil-based carbon, which was absorbed millions of years ago. If an ERF can capture and store a greater proportion of its carbon emissions than is produced from the combustion of non-biogenic (i.e. fossil-fuel) origin waste such as plastics, then the facility's overall emissions become negative. This would make the ERF a net reducer of atmospheric carbon emissions because the emission of biogenic carbon does not constitute a long-term net addition of carbon in the atmosphere.

This reinforces the vital importance of this strategic piece of infrastructure for London.

## 2. CCS TECHNOLOGY OVERVIEW

2.1. Carbon capture and storage (CCS) is an engineered solution which involves:

2.1.1. Capturing carbon dioxide ($CO_2$).

2.1.2. Conditioning and temporarily storing the $CO_2$ ready for transportation

2.1.3. Transporting the $CO_2$ from the emitter site to a permanent storage site through one or more modes of transport, e.g. pipeline, road or rail network, shipping

2.1.4. Injecting the $CO_2$ into shared permanent storage; typically in undersea locations for the UK

2.2. Carbon capture and utilisation (CCU) is the process of capturing $CO_2$ for use as a resource in products or industrial processes. There is a small market for $CO_2$ for use in a number of products including, for example, food and drinks, fertiliser, horticulture and transport fuels. CCU only delays carbon emissions to the atmosphere, as the captured $CO_2$ will be released to the atmosphere when products are used, consumed or broken up, in the longer term.

2.3. The Department for Business, Energy & Industrial Strategy (BEIS) has stated that: '*Carbon capture and utilisation (CCU) is an important option and offers economic opportunities, but it is unlikely, on its own, to be sufficient, as not all $CO_2$ usage technologies lead to permanent $CO_2$ reductions*.'. According to the Climate Change Committee (CCC): 'whilst CCU could help to facilitate progress [on CCUS] in the 2020s, the volume of $CO_2$ that can be utilised as a feedstock rather than permanently sequestered appear likely to be small relative to the necessary role for CCS in the long-term.' Approximately 600,000 tonnes $CO_2$ per annum from food and drink industry, medicine, and energy compared to the quantity of $CO_2$ expected to be captured from the ERF (approximately 700,000 tonnes $CO_2$ per annum).

2.4. Carbon Capture is a proven technology, in particular for oil and gas applications. In 2020, 40 million tonnes of $CO_2$ were captured using this technology globally. However, the use of this technology is new for the energy-from-waste sector. Pilot schemes are underway in the Netherlands and Norway, where both are receiving significant government funding. In the UK, SUEZ is investigating the feasibility of CCS on one of its facilities in Teeside where this plant benefits from close proximity to the proposed Net Zero Teeside CCS project.

2.5. Despite CCS being relatively new to the waste sector with only a few examples implemented with energy from waste, officers have already carried out significant preliminary work to understand the opportunities for the NLHPP. The recently conducted readiness assessment confirms the new ERF will be carbon capture ready and suitable for retrofit when the necessary economic drivers as well as a viable transport and storage solution are in place.

## 3. NLHPP CCS – FORWARD PLAN

3.1. The outline strategy sets out the background and the Authority's proposed strategic approach to the development of a CCS solution for ERF at the earliest opportunity.

3.2. The report provides an overview of the sector, the status of carbon capture technology including opportunities for transport and storage and a timeline for delivery of a potential solution. The outline strategy as described in the report will inform the forward plan of action for the Authority and provide Members with some of the key future decision points required to realise carbon capture at the Edmonton EcoPark. The outline strategy will be developed further as policy emerges in the coming months and years.

### CCS Deployment Programme

3.3. For a CCS project to be developed for the ERF, several workstreams need to be progressed, some simultaneously. To give an indication of timescales for this project, Section 6.1 Figure 4 of the outline strategy sets out an indicative programme. Implementation of the CCS Solution cannot start until the existing Energy from Waste (EfW) plant is demolished and the site cleared.

3.4. A delivery strategy and business case for the CCS solution will be developed and the technical engineering and planning activities related to the CCS solution completed. It is anticipated that a period of around five to ten years may be required to develop and deliver these activities which are expected to be complete by around 2030.

3.5. Following a period of implementation in the early 2030s, it is possible for a post-combustion carbon capture plant (PCC) to be operational at the EcoPark by around 2035. However, the successful implementation and operation of any PCC plant will greatly depend on available funding and financing as well as the establishment of a suitable T&S network connection for the ERF, and the securing of the appropriate planning and permitting consents. The 'off-site' T&S route is being investigated and will be informed by the mapping and options development included in the delivery strategy and initial stakeholder engagement.

3.6. Further significant stakeholder engagement will be required with relevant CCS T&S developers and operators as well as other CCS cluster members with the intention of CCS partnership formation and finalisation of the T&S routing from the Edmonton EcoPark site to a coastal staging location and transport to a permanent storage site. The viability of CCS at the EcoPark depends greatly on establishing a shared infrastructure hub or 'cluster' in Greater London and the south-east of England for carbon dioxide transport, intermediate storage and shipment to a long-term storage facility offshore. In particular it will depend on the success of clean hydrogen projects such as Project Cavendish in the south-east of England, which have similar infrastructure requirements for carbon dioxide intermediate and long-term storage.

3.7. It is anticipated that a CCS solution could be delivered from 2035 but, as described previously, the deployment timeline is dependent on available funding and financing and establishment of a suitable T&S network connection for the ERF, and the securing of the appropriate planning and permitting consents. As described in the outline strategy once the existing Energy from Waste (EfW) facility is removed there will be sufficient space at the EcoPark to install carbon capture equipment in the future.

**Business Models for Carbon Capture**

3.8. The government is developing a range of sector specific business models designed to incentivise carbon capture and stimulate investment by the private sector. The business models which are being consulted upon and developed by BEIS are designed to transfer / share some of the delivery and operating risks with Government. For the T&S owner / operators and industrial product manufacturers the increased capital expenditure, operating costs and risk is expected to be supported by government funding (for example from the £1 billion CCS Infrastructure Fund).

3.9. Four key business models have been the focus of government and industry expert groups to date. From the perspective of the Authority, the most relevant business models in development are the 'Transport and Storage Services Company business model' and the 'Industrial Carbon Capture (ICC) business model'. In May 2021, government issued an update to the ICC business model and made specific mention of government's 'minded to position' to support CCS on EfW facilities via the ICC business model, rather than other business models considered.

3.10. Under the ICC business model government support would be provided via payments under the ICC contract to an industrial emitter (for example, the ERF). However, as stated in the government's recent update report "*Further work needs to be done to determine how the potential use of an ICC business model to support CCUS in EfW facilities would align with the work government is undertaking on negative emissions*". This is considered a positive development and demonstrates government's increasing awareness of the role of energy from waste in relation to carbon capture. Officers will continue to monitor progress with business models and will provide updates to Members with developments as they evolve.

3.11. The business case for investment in CCS at the ERF cannot be fully established until the business model and contractual heads of terms are finalised by government. The Authority still has some opportunity to influence the design of the ICC business model for EfW facilities and through the Authority's advisers have started a conversation with BEIS to share plans for the ERF, offer expertise to help with policy formation and to explore the capital expenditure and operational funding opportunities arising for CCS on the ERF. Building a trusted relationship with a T&S company is a priority for this outline CCS Strategy.

## 4. STAKEHOLDER ENGAGEMENT

4.1. As part of the feasibility assessment work which is ongoing officers will look to identify options to find the most cost-effective $CO_2$ transportation route(s) to suitable coastal sites where $CO_2$ can be permanently stored. Potential partners for North London Waste Authority (NLWA) in the formation of a CCS cluster in the south east will be found by mapping $CO_2$ emitters across a wide area, defined by possible $CO_2$ transport corridors between the Edmonton site and the industrial clusters or related projects at the coastal locations.

4.2. The report refers to engagement with central government, and with others who have engaged to date in development of CCS schemes. These opportunities to support the Authority's development of its strategy and implementation plan will be progressed.

4.3. In developing the CCS strategy, officers will liaise with Directors of Environment in the seven constituent boroughs, and ensure that there is common understanding as the plans are progressed.

4.4. The Authority's outline strategy will be a public document, and information relating to the implementation of the proposals will be available to the public through the North London Heat and Power Project website.

## 5. EQUALITIES IMPLICATIONS

5.1. There are no implications relating to the Equality Act 2010 arising from this report or the outline Strategy.

## 6. COMMENTS OF THE LEGAL ADVISER

6.1. The Legal Adviser has been consulted in the preparation of this report and comments have been incorporated

## 7. COMMENTS OF THE FINANCIAL ADVISER

7.1. The Financial adviser has been consulted in the preparation of this report and comments have been incorporated.

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# APPENDIX A NLHPP CARBON CAPTURE AND STORAGE: OUTLINE STRATEGY - BACKGROUND AND STRATEGIC APPROACH TO IMPLEMENTATION

# North London Heat and Power Project Carbon Capture and Storage: Outline Strategy - Background and Strategic Approach to Implementation

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# 1 Introduction

This document sets out the background and the Authority's strategic approach to the development of a Carbon Capture and Storage (CCS) solution for the Energy Recovery Facility (ERF) at the Edmonton EcoPark by 2035. This outline strategy document describes the steps needed to inform a realistic delivery plan for CCS, examines the issues which will need to be addressed, and highlights the key decision points expected. It has been prepared in anticipation of the construction of a replacement ERF at the Edmonton EcoPark which is being delivered through the North London Heat and Power Project (NLHPP). The ERF was authorised by the North London Heat and Power Generating Station Order 2017.

As is stated in the most recent Intergovernmental Panel on Climate Change (IPCC) report '*the continued growth of atmospheric $CO_2$ concentrations over the industrial era is unequivocally due to emissions from human activities*'[1]. There is now overwhelming evidence that $CO_2$ and other gases produced by human activities are altering the Earth's climate, leading to negative impacts such as higher average temperatures, rising sea levels and more extreme weather events. The carbon capture industry both globally and in the UK is a rapidly developing sector. The urgency and critical importance of this technology has increased significantly. There is broad international consensus that CCS is essential in meeting the Paris Agreement of limiting the global average temperature rise to 1.5ºC above pre-industrial levels, and that without CCS Net Zero is not achievable.

The government will play a central role in bringing forward this complex infrastructure in partnership with industry over the next decade and has been conducting a series of consultations and competitions in an attempt to further progress this technology in the UK. The Authority recognises the important opportunity which CCS technology offers to decarbonise the waste management sector. This outline Strategy is therefore a live document which will be regularly reviewed and updated as the emerging policy in this area develops over the coming months and years.

CCS refers to a set of technologies which together capture carbon dioxide ($CO_2$) from flue gases released during industrial processes (such as power plants or industrial processes) before it is released into the atmosphere. The captured $CO_2$ can be transported for permanent storage in deep underground geological formations, for example, depleted oil and gas reservoirs or natural saline aquifers. The Authority is undertaking further work on CCS feasibility to progress how best to apply this solution to the ERF to further improve the sustainability credentials of the NLHPP, and potential generate net negative carbon emissions.

An alternative to storing the captured $CO_2$ is to use it in the creation of new fuels or products, for example, concrete for construction or as a resource in industrial processes. However, as it discussed later in this document, the market for $CO_2$ in the UK is small (around 600,000 tonnes $CO_2$ per year or around a fifth of Europe's total consumption). Therefore, it is not considered a viable outlet for the carbon emissions produced by the ERF (around 700,000 tonnes per year including fossil and non-fossil fuel emissions). Additionally, carbon capture 'utilisations' only delays carbon emissions to the atmosphere, as the captured $CO_2$ will be released to the atmosphere when products are used, consumed or broken up, in the longer term. $CO_2$ 'utilisation' is not considered in detail as part of this strategic approach however, the Authority will continue to monitor the sector as utilisation technologies develop.

This outline strategy has been structured as follows:

- Section 2 of this report provides a description of Carbon Capture and Storage;
- Section 3 includes a status review of CCS in terms of climate change drivers, the global CCS sector, UK CCS policy development, funding and business models, followed by a summary of UK CCS projects and partnerships;
- Section 4 comprises a strategic discussion of developing a CCS solution for the ERF;

[1] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf

- Section 5 provides an update on the Authority's CCS work to date;
- Section 6 outlines a forward plan of activities for CCS for the ERF;
- Section 7 identifies future decisions that need to be considered for the deployment of a CCS solution for the ERF; and
- Section 8 provides a report summary and key messages.
- Appendix A contains a glossary and list of abbreviations used.

# 2 Carbon Capture Usage and Storage

## 2.1 Overview

The combustion of residual waste in an energy from waste (EfW) facility results in the generation of climate-relevant emissions, which mainly comprise $CO_2$. A significant fraction of the incoming waste-based fuel at EfW facilities, like the ERF, will be of biogenic origin, including paper, cardboard, wood, food waste and garden trimmings. Carbon emissions of biogenic waste are not climate-relevant and are considered 'short cycle' as the carbon dioxide was recently absorbed by growing matter, as opposed to fossil-based carbon, which was absorbed millions of years ago.

The Authority's constituent boroughs do, and will continue to, provide extensive and well performing recycling and composting services. However, there will always be some waste which is not suitable for recycling. For example, materials mixed in with residual waste are typically too contaminated to be repurposed into new products. If an EfW facility can capture and store a greater proportion of its carbon emissions than is produced from the combustion of non-biogenic (i.e. fossil-fuel) origin waste such as plastics, then the EfW facility's overall emissions become negative. This makes the EfW facility a net reducer of atmospheric carbon emissions.

As a result, through a CCS solution for the ERF, NLWA aims to capture the direct $CO_2$ flue gas emissions of the ERF, which amount to approximately 700,000 tonnes $CO_2$ per year (equivalent to treating 700,000 tonnes per year of residual waste at the ERF). This includes both biogenic and non-biogenic emissions. The relevance of capturing the $CO_2$ from the ERF and its use or permanent storage are described in more detail below.

The next sections describes carbon capture and utilisation, and carbon capture and storage.  The proposed strategic approach for NLWA is to use CCS rather than CCUS, for the reasons set out below.

## 2.2 What is carbon capture and utilisation?

Carbon Capture Usage and Storage (CCUS) and CCS are terms used in UK policy and legislation. Both CCUS and CCS refer to 'capture' of carbon dioxide ($CO_2$) arising from the combustion of fossil fuels in, for example, power station or industrial processes. The captured $CO_2$ can then be transported for use as a resource to create products (referred to as 'utilisation' and explained further below) or for permanent storage in deep underground geological formations (referred to as 'storage' under CCS).

Carbon capture and utilisation (CCU) is the process of capturing $CO_2$ for use as a resource in products or industrial processes. In policy terms, it is often distinguished from CCUS or CCS when referring specifically to use of carbon dioxide as a product for use by industry (for example, stored in concrete or as an industrial product for chemical manufacturing) as opposed to permanent underground injection. There is only a small market for $CO_2$ for use in a number of products including, for example, food and drinks, fertiliser, horticulture and transport fuels. CCU only delays carbon emissions to the atmosphere, as the captured $CO_2$ will be released to the atmosphere when products are used, consumed or broken up, in the longer term.

The Department for Business, Energy & Industrial Strategy (BEIS) has stated that: *'Carbon capture and utilisation (CCU) is an important option and offers economic opportunities, but it is unlikely, on its own, to be sufficient, as not all $CO_2$ usage technologies lead to permanent $CO_2$ reductions.'*[2]. According to the Climate Change Committee (CCC): '*whilst CCU could help to facilitate progress [on CCUS] in the 2020s, the volume of $CO_2$ that can be utilised as a feedstock rather than permanently sequestered appear likely to be small relative to the necessary role for CCS in the long-term.*'.

2 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/651222/cement-decarbonisation-action-plan.pdf

CCU is not considered to form a major part of the overall carbon capture solution for EfW facilities including the ERF, as opposed to permanent $CO_2$ storage for the following reasons:

- The value of $CO_2$ is low. A decade ago, the Competition Commission (now the Competition & Markets Authority) estimated the value of the UK's $CO_2$ wholesale market as just £15 million.
- The supply of $CO_2$ requires purification to 99% to meet Food Standards Agency standards for 'food-grade $CO_2$' for all uses in the industry. Upgrading of $CO_2$ to food grade quality can be cost prohibitive.
- The market for $CO_2$ in the UK is small compared to the quantity of $CO_2$ requiring removal. A report commissioned by the Food & Drink Federation states that: 'The UK is one of Europe's largest users of $CO_2$. Industry sources estimate annual consumption of around 600,000 t$CO_2$; around a fifth of Europe's total consumption'.[3]
- Captured $CO_2$ from EfW facilities would compete with existing $CO_2$ arrangements for industrial gases by the four main companies including Air Liquide, Air Products, BOC (Linde) and Praxair, which provide $CO_2$ as by-products from, for example, CF Fertilisers UK fertiliser manufacturing (Billingham and Ince), bio-ethanol production, and imports.
- CO2 can be permanently stored in concrete for use in construction by a chemical process referred to as mineralisation. However, there is no assessment of this solution over time yet, and therefore it is unlikely that this technology would be accepted as a suitable option for a number of years. In addition, the quantities required are small, posing, again, the barrier of captured $CO_2$ supply, exceeding demand.

Therefore, for the reasons set out above the Authority has not progressed the 'utilisation' of $CO_2$ for use in industrial process or as a product as part of the strategic to carbon capture for the ERF. The Authority will continue to monitor the sector as the technology develops.

## 2.3 What is carbon capture and storage?

CCS is an engineered solution which involves:

- Capturing $CO_2$ before it is emitted to atmosphere through a complex chemical process.
- Conditioning and temporarily storing the $CO_2$ ready for transportation. Conditioning the CO2 includes purifying the gas (as impurities in the gas can damage storage vessels and pipelines), compressing and temperature controlling it to keep it in its gaseous state whilst reducing the volume of storage required.
- Transporting the $CO_2$ from an emitter site to a permanent storage site through one or more modes of transport, for example, pipeline, road haulage, rail freight, or shipping. The environmental impact of the mode of transport would be assessed as part of the development of an implementation plan.
- Injecting the $CO_2$ into shared permanent storage, typically in subsea locations for the UK.

There are several methods of capturing $CO_2$ before it is emitted to atmosphere from industrial processes including: 1) Oxyfuel, where fuel is combusted in oxygen rather than air to produce flue gas that is rich in $CO_2$; 2) Pre-combustion, where $CO_2$ is removed from a synthesis gas prior to combustion; and 3) Post-combustion, where dilute $CO_2$ (approximately 10% by volume of the flue gas) is removed from the flue gas created from a process. For the ERF, post-combustion capture is the relevant carbon capture method.

Figure 1 provides an overview of the CCS value chain, which is complex including the four main elements mentioned above. The successful deployment of CCS infrastructure relies on a close

[3] https://www.fdf.org.uk/globalassets/resources/publications/falling-flat-lessons-from-the-2018-uk-co2-shortage.pdf

partnership and collaboration between government and industry to deliver against the ambition to reduce $CO_2$ emissions to atmosphere and mitigate climate change. There is further discussion of the CCS technology and processes in Section 0 and Section 5 respectively.

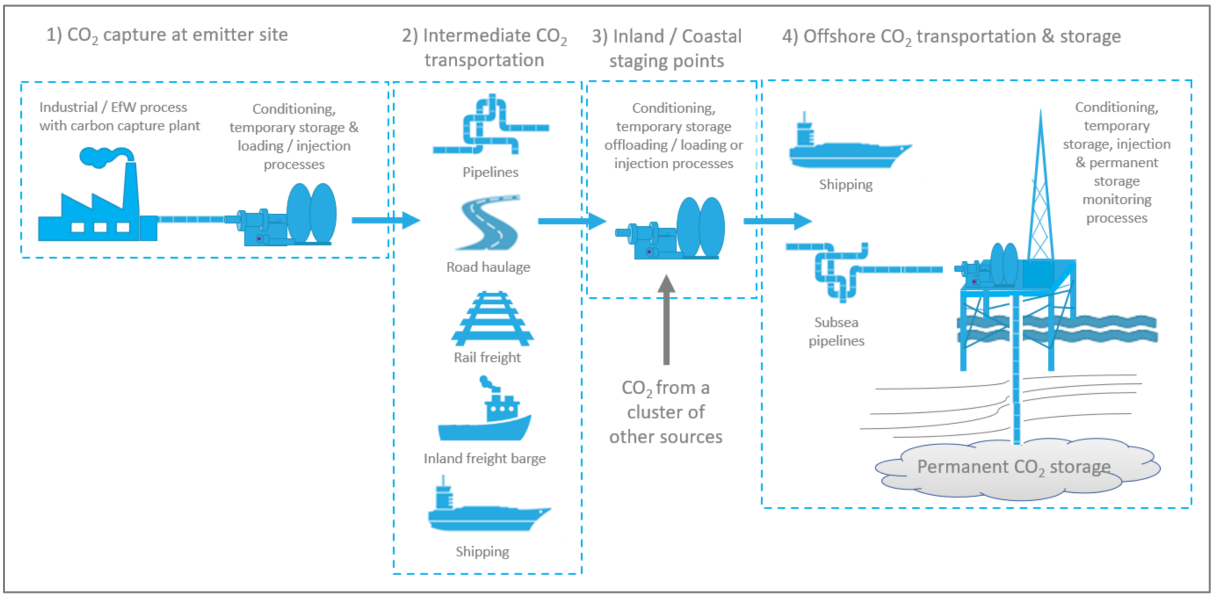


*Figure 1: Overview of carbon capture and storage value chain*

In Figure 1, the plant components shown in Step 1 ‘$CO_2$ capture at emitter site’ are elements of the CCS value chain solution expected to be in the control of the Authority. Step 2 to Step 4, comprising ‘Intermediate $CO_2$ transportation’ to ‘Inland/costal staging points’, and ‘Offshore $CO_2$ transportation and storage’ are not in the direct control of the Authority. These steps rely on the development of shared infrastructure, likely owned and operated by a third party and treated as regulated asset base (RAB).

There are important interdependencies across all stages of the CCS value chain outlined above. This is discussed further in Section 0 ‘Developing a CCS Solution for the ERF’.

# 3 CCS Status Review

## 3.1 Global, national and regional climate change drivers

Tackling the climate emergency has moved up the global, national, and regional agenda of both government and industry. There is a broad international consensus that CCS is essential in meeting the Paris Agreement[4] of limiting the global average temperature rise to 1.5ºC above pre-industrial levels, and that without CCS Net Zero[5] is not achievable. The urgency of climate change was again reinforced in the most recent IPCC report (6th Assessment Report Workign Group 1[6]). In almost all emissions scenarios set out in the report, global warming is expected to hit 1.5C in the early 2030s. Report explains that if net-zero $CO_2$ emissions along with strong reductions in other greenhouse gases are not achieved the climate system will continue to warm with severe consequences for the planet.

The IPCC 6th Assessment Report highlights that emission scenarios that limit global warming to 1.5ºC or 2ºC typically assume the use of carbon removal activities in combination with greenhouse gas emissions reductions. The Global CCS Institute highlights the strategic importance of CCS in a Net Zero emissions future[7]. The International Energy Agency (IEA) predicts a need to increase CCS globally from around 40 million tonnes $CO_2$ per year in 2020 to around 5,635 million tonnes $CO_2$ per year in 2050, in order to meet decarbonisation targets[8]. In Europe, the long-term climate strategy target for CCS is large, requiring up to 600 million tonnes $CO_2$ per year capture capacity.

The Climate Change Committee (CCC) states that for the UK to achieve its Net Zero commitment, CCS is a necessity and not an option[9]. The CCC's 'Balanced Net Zero Pathway' predicts a need for 104 million tonnes $CO_2$ per year CCS capacity to achieve Net Zero by 2050. In their Sixth Carbon Budget[10], the CCC also states that by 2050, the carbon emission levels of the waste sector can be reduced by 75% relative to today's carbon emissions levels. It also suggests that all new EfW facilities and extensions to facilities should be fitted with post-combustion carbon capture (PCC) plants starting from early 2040s (or 'Tailwind Net Zero Pathway' by early 2020s) or should be built as 'CCS ready', with CCS fitted to all facilities by 2050.

Through the 'Zero Carbon London: 1.5ºC compatible plan'[11], the Mayor of London declared a climate emergency and set an ambition for London to be a Zero Carbon city by 2030. In addition, six out of the seven NLWA boroughs declared a climate emergency and/or have set out a carbon reduction strategy.

According to Policy Connect (an independent, cross-party not-for-profit organisation with two decades in policy work), the UK government should support the development and integration of CCUS technology into EfW facilities, in anticipation of a future carbon tax. Following 'The future of UK carbon pricing consultation'[12] (last updated June 2020), there is certainty that the EfW sector will not be exposed to carbon pricing until at least 2025, but the Sixth Carbon Budget suggests that capturing all carbon emissions arising from the combustion of waste should be introduced, and UK government policy development is now considering this.

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[4] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[5] Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.
[6] https://www.ipcc.ch/report/ar6/wg1/#TS
[7] https://www.globalccsinstitute.com/resources/global-status-report/
[8] https://www.iea.org/reports/net-zero-by-2050
[9] https://www.theccc.org.uk/wp-content/uploads/2021/06/Progress-in-reducing-emissions-2021-Report-to-Parliament.pdf
[10] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf
[11] https://www.london.gov.uk/sites/default/files/1.5_action_plan_amended.pdf
[12] https://www.gov.uk/government/consultations/the-future-of-uk-carbon-pricing

The Energy Systems Catapult (an independent, not-for-profit centre working with the non-departmental public body Innovate UK)[13] reports that a significant proportion of the EfW facilities in the UK are relatively newer than other industrial facilities, and therefore have a longer life to benefit from CCS investment. On a lowest system transition cost basis, fitting CCS to EfW facilities could constitute 20% of all carbon captured in the UK by 2050.

## 3.2 The global CCS sector

It is important to understand the state of CCS developments and current policies around the world. This is a rapidly developing sector and so further innovation is expected. Developments will be monitored so that they can be incorporated into plans which are developed based on this outline strategy and any updates.

According to the Global CCS Institute [14], today there are 65 commercial CCUS facilities, of which 26 are operating, 21 are in early development, 13 are in advanced development reaching front end engineering design (FEED), three are under construction, and two have suspended operations (one due to the economic downturn, the other due to fire). There are another 34 pilot and demonstration-scale CCUS facilities in operation or development and eight CCUS technology test centres.

There is a need for scaling up the CCS capacity globally but the costs for CCS technologies will need to fall and economic incentives (e.g. carbon tax or carbon credits) are required to make projects bankable. For example, the involvement of the United States (US) in 12 of the 17 new CCS facilities in 2020 was largely due to the enhanced '45Q tax credit' signed into US law in 2018. The current position is that CCS facilities in operation can capture and permanently store around 40Mt$CO_2$ per year.

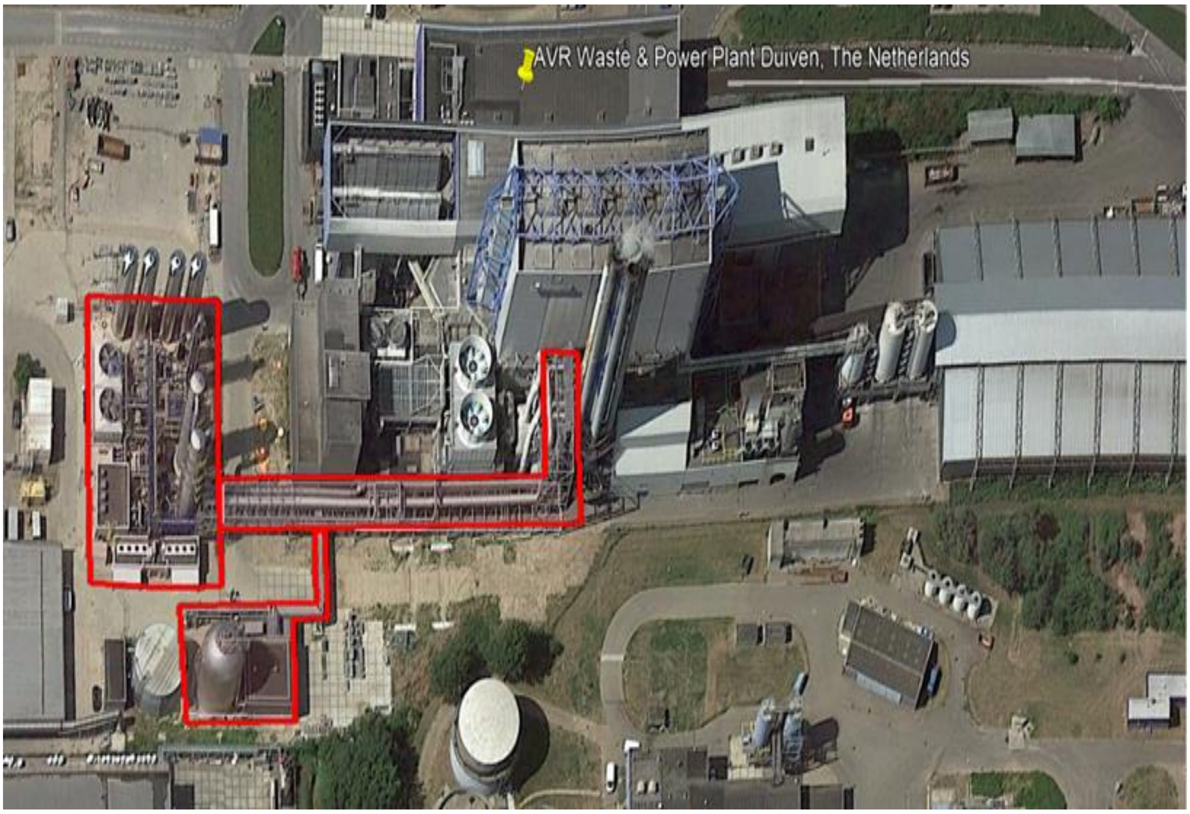


*Figure 2: AVR Waste and Power Plant with post-combustion carbon capture (PCC) plant highlighted by the area outlined in red*

[13] https://es.catapult.org.uk/reports/energy-from-waste-plants-with-carbon-capture/
[14] https://www.globalccsinstitute.com/resources/global-status-report/

In the Netherlands, waste management company AVR Duiven operates a full-scale post-combustion carbon capture (PCC) plant, which has a capacity of 100,000 t$CO_2$ per year[15] (see Figure 2). The captured $CO_2$ is used in greenhouse horticulture in Duiven, and operates for around six months per year, to match the demand for $CO_2$ in the crop growing season. In 2020, AVR reported that they only captured 31,000 tonnes of carbon due to 'teething problems' and the seasonal operational regime[16].

A key CCS project is also in development at the Twence[17] EfW facility in the Netherlands. Using Aker's Just Catch modular carbon capture solution, it will have a capacity of 100,000 tonnes $CO_2$ per year[18]. The PCC plant was expected to be commissioned in 2021 but the project was delayed seeking funding from the Netherlands government. The European Commission granted the Netherlands state investment aid of €14.3 million (or £12.2 million) for the PCC plant on 30 July 2021[19].

The Norwegian government and project partners Northern Lights (incorporated in March 2021 as a partnership between Equinor, Shell and Total Energies), Norcem (wholly owned subsidiary of Heidelberg Cement Group) and Fortum Oslo Varme (owned 50% by Finnish energy company Fortum Oy and 50% by Oslo Municipality) are developing the NOK 25.1 billion (or £2 billion) Langskip Project[20] (also referred to as Longship); a full scale CCS project.

Northern Lights[21] is the transport and storage (T&S) component for Norway's Longship project providing the infrastructure for shipping, subsea transport and permanent carbon storage. Phase one of the project is expected to be completed in mid-2024 with an initial capacity of up to 1.5 million tonnes $CO_2$ per year. It is also the first project offering 'carbon storage as a service' to industrial emitters across Europe, being open to shipping of $CO_2$ from other countries. A change in international maritime laws (The London Protocol) has enabled this, now allowing transboundary shipment of $CO_2$ for permanent subsea storage under tight environmental controls[22].

Norcem is the sole producer of cement in Norway, and its cement plant in Brevik (approximately 160km south-west of Oslo) is planned to implement carbon capture with a capacity to capture 400,000 tonnes $CO_2$ per year where the captured $CO_2$ is transported for permanent storage at Northern Lights. Norcem have reported that the total cost (investment and operating costs for five years) for the CCS is estimated at NOK 11.2 billion (or £915 million)[23], and is expected to be operational in 2023/24.

Fortum Oslo Varme is planning to capture $CO_2$ from the Klemetsrup EfW facility in Oslo, Norway. The captured $CO_2$ will be liquefied and temporarily stored in tanks at Klemetsrud. From there, the liquified $CO_2$ will be transported by road in tank trucks to the Oslo harbour where there will be storage capacity for four days of capture operations. The $CO_2$ will then be shipped to Northern Lights for permanent storage.

In 2019, Fortum Oslo Varme completed a carbon capture pilot project (capacity of approximately 3.5 tonnes $CO_2$ per day, an average $CO_2$ capture rate of 95% and 5,500 operating hours) to capture ultimately 400,000 tonnes $CO_2$ per year at the Klemetsrup EfW facility[24]. Based on the Fortum status report of the carbon capture pilot plant, Fortum Oslo Varme received a conditional offer of

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15 https://www.avr.nl/en/co2-installation/waste-to-energy-company-tackles-co2-emissions-with-large-scale-co2-capture-installation/
16 https://www.avr.nl/wp-content/uploads/2021/04/AVR-AnnualReport2020.pdf
17 Twence was established by fourteen municipalities in Twente. With a common vision for waste processing, the organisation has developed since 1986 into a figurehead and source of inspiration in the field of the circular economy in the east of the Netherlands.
18 https://www.akersolutions.com/news/news-archive/2019/aker-solutions-signs-carbon-capture-contract-with-twence-in-the-netherlands/
19 https://ec.europa.eu/info/news/state-aid-commission-approves-eu143-million-dutch-aid-support-carbon-capture-and-use-facility-2021-jul-30_en
20 https://langskip.regjeringen.no/longship/article/
21 https://northernlightsccs.com/what-we-do/
22 IEAGHG-2021-TR02-Exporting-CO2-for-Offshore-Storage-The-London-Protocol-s-Export-Amendment-and-Associated-Guidelines-and-Guidance.pdf (club-co2.fr)
23 https://www.norcem.no/en/CCS%20at%20Brevik
24 https://www.fortum.com/about-us/newsroom/press-kits/carbon-removal/fortum-oslo-varme-and-our-carbon-capture-project

NOK 3 billion (or £245 million) from the Norwegian government for co-funding, provided that the project ensures sufficient self-financing of the remaining NOK 3.8 billion (or £310 million), through the European Union (EU) and/or other sources[25]. Fortum Oslo Varme has been shortlisted for funding from the EU Innovation Fund and has recently submitted its full funding application for the second stage of funding evaluation. It is expected that the full-scale PCC plant will be operational in 2024 subject to obtaining the required funding.

The Authority will continue to closely monitor the energy from waste market in relation to carbon capture both globally and in the UK. Where applicable any learnings from these projects will be incorporated into any future strategic plans.

## 3.3 CCS policy development in the UK

Deploying CCS at scale in the UK is an ambition of the government for a deep decarbonisation of the economy, and protection of remaining heavy industrial businesses. In the 2017 'Clean Growth Strategy'[26] (one of the four grand challenges of the Industrial Strategy), the UK government, sets out the need to work in partnership with industry, through a new CCUS Council, to put the UK on a path to deploy CCS at scale, and to maximise its industrial opportunities.

The Industrial Clusters Mission[27] focused funding on the development of UK industrial clusters or hubs at coastal locations, comprising industrial centres where the greatest level of $CO_2$ point emissions is concentrated. These industrial clusters are critical for the scale up and acceleration of CCS deployment as they provide the anchor loads (of captured $CO_2$) to justify and drive initial development of shared carbon T&S infrastructure, in particular coastal staging points, sub-sea pipelines, offshore structures (platforms) and permanent subsea $CO_2$ storage (see Figure 3). Once operational, CCS implementations from further afield will be able to exploit them by forming looser clusters that justify onshore transportation routes to the coastal staging points.

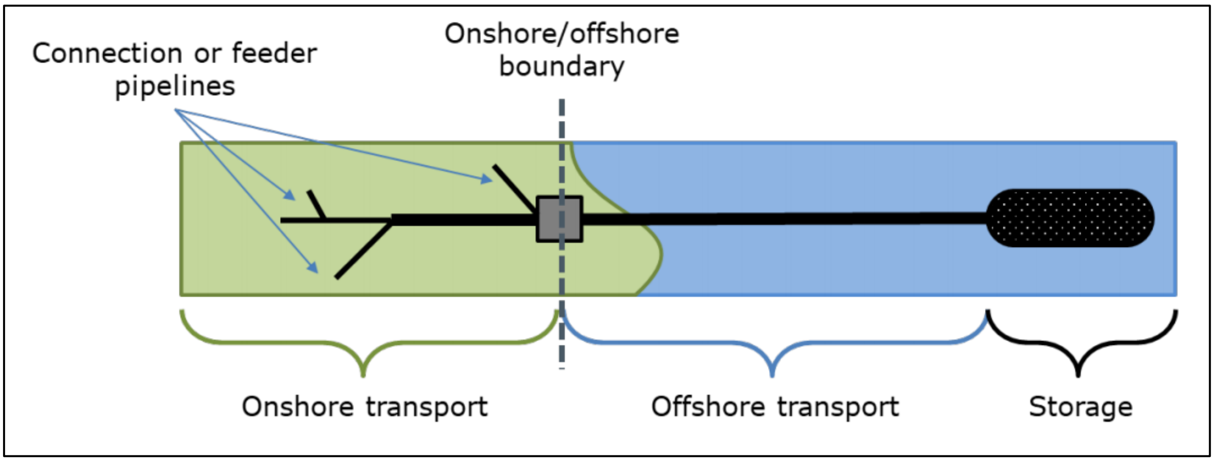


*Figure 3: Illustration of a notional CCS cluster (BEIS)*

In support of these developments, UK Research and Innovation provided two phases of funded support from the Industrial Decarbonisation Challenge Fund[28] for Cluster development (Phase 1) and in March 2021, CCS FEED studies for nine CCS projects (Phase 2).

Six major industrial CCS clusters / coastal staging points were originally identified:

- Scotland – Including Grangemouth, and St Fergus, where a fifth of the UK's gas supply lands.

[25] https://www.fortum.no/om-oss/miljo-samfunnsansvar/dette-er-karbonfangst-og-lagring-ccs/status-karbonfangstprosjektet-pa-klemetsrud
[26] https://www.gov.uk/government/publications/clean-growth-strategy
[27] https://www.gov.uk/government/publications/industrial-clusters-in-england
[28] https://www.ukri.org/news/ukri-awards-171m-in-uk-decarbonisation-to-nine-projects/

- Humberside (Zero Carbon Humber) – Three sites comprising the largest UK industrial cluster by $CO_2$ emissions.
- Teesside (Net Zero Teesside) – A historic industrial cluster, with easy access to high quality North Sea $CO_2$ storage options.
- Northwest – Home of the HyNet project, demonstrating Hydrogen generation, distribution and use for industrial fuel switching.
- South Wales – the UK's second largest industrial cluster stretching along the South Wales coast and dominated by Steel manufacture.
- Southampton – The UK's largest oil refinery operation (ExxonMobil) but the least developed UK industrial cluster.

In 2020, UK government's response to a consultation on the 'Reuse of Oil and Gas Assets for Carbon Capture and Storage Projects'[29], recognised the potential for cost savings and skilled job protection from doing this, identifying depleted oil and gas reservoirs, wells, trunk pipes, platforms and other infrastructure as having potential for reuse. The Oil and Gas Authority (OGA)[30] states the UK Continental Shelf has over 500 potential sites with $CO_2$ storage capacity[31] to fully support the UK's requirements covering hundreds of years. As a result of this work, all UK $CO_2$ storage sites are expected to be subsea.[32]

In the March 2020 Budget, UK government announced a CCS Infrastructure Fund (CIF) of at least £800 million to provide capital expenditure (CAPEX) in support of this policy and in November 2020, the government's 'Ten Point Plan for a Green Industrial Revolution'[33] clarified CCS policies following a two year collaboration of key CCS stakeholders. This included a commitment to establish CCS in two industrial clusters by mid 2020s, and four in total by 2030, capturing up to 10 million tonnes $CO_2$ per year. The CIF was also raised to £1 billion, and government committed to developing revenue mechanisms to support ongoing operation of CCS projects.

The government's ambition extends beyond this; with an aim of deploying CCS for all industrial clusters. These first four industrial clusters are expected to be early adopters, implementing first of a kind projects, attracting early-stage investors and driving down costs through innovation and shared learning. It is anticipated that $CO_2$ pipelines and transportation routes will develop, joining up the industrial clusters in the long-term and creating a new class of privately owned, regulated national assets. Supporting this, government is currently consulting on a future $CO_2$ regulator[34] to oversee these developments and the business models supporting them, described below.

## 3.4 Current UK CCS funding and business models

Working with expert groups from the CCS sector, government is continuing to develop further CCS policy and business models which will support the major industrial sectors as they develop and operate carbon capture plant, and the investors who will develop and operate the associated T&S infrastructure.

29 https://www.gov.uk/government/consultations/carbon-capture-usage-and-storage-ccus-projects-re-use-of-oil-and-gas-assets
30 https://www.ogauthority.co.uk/the-move-to-net-zero/carbon-capture-and-storage/
31 http://www.co2stored.co.uk/home/index
32 Neither the South Wales nor the Southampton cluster have connection points to offshore storage sites and both clusters may need to develop port facilities and shipping transport solutions to export captured $CO_2$ to a coastal staging point at a UK or overseas site with permanent storage facilities.
33 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf
34 https://www.gov.uk/government/consultations/carbon-capture-usage-and-storage-ccus-duties-and-functions-of-an-economic-regulator-for-co2-transport-and-storage

Four key business models have been the focus of the expert groups to date. Most importantly for NLHPP, these include the ‘Transport and Storage Services Company (T&S) business model’ and the ‘Industrial Carbon Capture (ICC) business model’[35].

Following an industry consultation[36] in March 2021, government issued an update to the ICC business model[37] in May 2021 made specific mention of government’s ‘minded to position’ to support CCS on EfW facilities via the ICC business model, rather than other business models considered.

The eligibility criteria for initial funding of EfW facilities via ICC business model fits well with the ERF from a technical design and planning status perspective.

ICC contracts of up to 15 years would reimburse the fees charged by the T&S operator for use of the infrastructure, covering its operational expenditure (OPEX). The ICC contract will also offer a payment per tonne of carbon captured, covering operational expenses and in addition the repayment of a rate of return on CAPEX on CCS equipment. Other aspects of the ICC business model and CIF support for EfW facilities are not yet finalised.

In May 2021, BEIS published the guidance on how they would allocate funding from the CIF[38]. The sequencing approach announced is split into two Tracks, each with two Phases. In Track 1 two clusters will be selected that demonstrate readiness for deployment in the mid-2020s and the Track 2 clusters by 2030.

For each Track, Phase 1 will be open to applications from cluster organisations which demonstrate a viable, integrated set of T&S infrastructure and capture projects. Phase 2 will be open to individual capture projects associated with clusters selected at Phase 1 and winning projects will enter negotiations with government for funding support via the CIF, which will primarily support capital expenditure on T&S networks and ICC projects, and CCS business models.

Key for NLHPP, the Phase 2 process is open to applications from projects across the UK regardless of geographic location and proximity to a T&S network, but projects will be required to demonstrate a provisional agreement covering a $CO_2$ transport solution and access to permanent $CO_2$ storage.

Building a trusted relationship with a credible and technically feasible T&SCo (a company licensed to provide transport and storage services) is therefore a priority for this outline CCS strategy. The T&S operators will need to know in advance about the volume of $CO_2$ that NLWA would need to ship through their network and permanently store so that they can reserve capacity in their pipework and store or build infrastructure to meet future demand.

The Net Zero Innovation Portfolio[39] of BEIS, released in 2021, provides funding for low-carbon technologies and systems including advanced CCUS. Competitions will be launched throughout 2021 with the aim of reducing costs for capture and sequestering of $CO_2$ and accelerate development and deployment of next generation carbon capture technologies from 2025.

In 2021, BEIS also published a £20 million call for CCUS Innovation[40]. It will provide grant funding to innovation projects that significantly reduce the cost of capturing, using and sequestering $CO_2$, or accelerate development and deployment of next generation carbon capture technologies on industrial, waste or power sites.

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[35] Other business models developed include the Dispatchable Power Agreements, the Low Carbon Hydrogen contracts and the Bioenergy with CCS contracts.

[36] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/909706/CCUS-government-response-business-models.pdf

[37] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/984119/industrial-carbon-capture-icc.pdf

[38] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/984001/ccs-infrastructure-fund-cif-design.pdf

[39] https://www.gov.uk/government/collections/net-zero-innovation-portfolio

[40] https://www.gov.uk/government/publications/call-for-ccus-innovation

*Key Consideration:* The business case for investment in CCS at the ERF cannot be fully established until the business model and contractual heads of terms are finalised by government. NLWA still has some opportunity to influence the design of the ICC business model for EfW facilities and the Authority has started a conversation with BEIS to share plans for the ERF, offer expertise to help with policy formation and to explore the CAPEX and revenue funding opportunities arising for CCS on the ERF. Building a trusted relationship with a T&SCo is a priority for this outline CCS strategy.

## 3.5 UK CCS projects and partnerships

The section provides a summary of the industrial clusters and projects which have developed across the UK in recent times. As discussed, industrial clusters are critical for the scale up and acceleration of CCS deployment as they provide the anchor loads (of captured CO2) to justify and drive initial development of shared carbon T&S infrastructure. In continuing the strategic development and implementation plans for the ERF carbon capture, NLWA will seek to learn from the development of the projects and cluster listed blow and establish relationships with relevant organisations over the coming months.

The Acorn project[41] based at St Fergus in North East Scotland has an existing carbon storage licence from an early CCS pilot project. It is now repurposing the existing Goldeneye pipeline to take $CO_2$ captured from blue hydrogen production directly to its sub-sea storage site, minimising capital costs. It also plans to develop deep water port facilities at Peterhead for $CO_2$ to be shipped for permanent storage from elsewhere. The project aims to be the T&S system for Scottish carbon emissions and in operation from 2024.

Net Zero Teesside Cluster[42] involving partners SUEZ Group (waste management company), BP and local government, are working together on plans for the UK's first decarbonised industrial hub in Teesside. The CCS projects are planned to be commissioned by 2026 to capture up to 10 million tonnes $CO_2$ per year by 2030.

Zero Carbon Humber Cluster[43] involves key partners Equinor, Drax and National Grid Ventures working jointly with Associated British Ports, Centrica Storage, Phillips 66, PX Group, SSE Thermal, Saltend Cogeneration Company, VPI-Immingham LLP and Uniper. Net Zero Humber aims to be commissioned by 2026 with realistic pathways to achieve Net Zero as early as 2030.

The Northern Endurance Partnership[44] was formed in late October 2020 by BP, Eni, Equinor, National Grid, Shell and Total. With BP acting as Operator, the Partnership will develop offshore transport and storage infrastructure in the UK North Sea to serve the Net Zero Teesside and Zero Carbon Humber industrial clusters.

Net Zero North West[45] is an industrial cluster stretching across the Liverpool, Manchester, Cheshire to the North Wales coast. The stakeholder grouping is led by Peel NRE, Tata Chemicals, CF Fertilisers, Siemens, Encirc, Inovyn, Storengy and the North West Leadership team. The Net Zero North West cluster is focused on decarbonising the North West using a combination of technologies including smart grids, small modular nuclear, tidal and wind, hydrogen and CCS.

The HyNet Project[46] in the North West Cluster is led by Progressive Energy, Cadent, CF Fertilisers, Eni UK, Essar, Hanson, INOVYN (part of the INEOS Group) and the University of Chester. The project aims to produce blue hydrogen at Stanlow Refinery by 2025, and new pipelines will be built to supply hydrogen for use in industry, power generation, public transport, heavy goods vehicles and homes across the North West Cluster. HyNet will also capture and store $CO_2$ emissions produced by energy intensive industries by repurposing existing gas network from the Point of Ayr gas terminal on

[41] https://theacornproject.uk/
[42] https://www.netzeroteesside.co.uk/
[43] https://www.zerocarbonhumber.co.uk/
[44] https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/northern-endurance-partnership-to-develop-offshore-ccus-infrastructure.html
[45] https://netzeronw.co.uk/
[46] https://hynet.co.uk/

the south coast of the Wirral to reach the depleted Hamilton and Lennox gas fields for $CO_2$ storage. By 2030 HyNet could be capturing 10 million tonnes $CO_2$ tonnes year.

The South Wales Industrial Cluster stretches along the coast from Pembroke to Port Talbot and includes a wide variety of industries dominated by iron and steel production, oil refineries and chemicals. Having no suitable subsea structures nearby for $CO_2$ storage, this cluster is assessing options for piping $CO_2$ to a suitable port area for shipment to permanent storage with a UK or European T&S operator.

Hydrogen East[47], a not-for-profit group founded by New Anglia Energy, Openergy, EDF Energy, TCP ECO and CPH2, is looking to establish a hydrogen economy in the East of England. Hydrogen could be generated via three routes: Bacton, on the North Norfolk coast, is ideally placed for blue hydrogen production, as this is where 30% of the UK gas supply is landed; Offshore wind farms in the Norfolk farm and the nuclear facility at Sizewell C, should this go ahead, could also support generation of low carbon / green hydrogen[48]. Generating blue hydrogen by steam or auto-methane reforming with CCS here would support decarbonisation of the national gas supply. The $CO_2$ captured could be piped to offshore gas storage options nearby in the North Sea.

Project Cavendish[49] on the Isle of Grain, Kent, is a network innovation project involving Cadent Gas, Southern Gas Networks and National Grid Gas Transmission. The project is developing a blue hydrogen[50] production facility with carbon capture which will initially inject up to 20% hydrogen into the national gas supply but eventually hopes to deliver 100% hydrogen supply for London and the South of England. The project is considering the $CO_2$ T&S infrastructure required which initially be shipped out to one of several UK cluster storage facilities or European alternatives (e.g. Northern Lights).

Enfield Power Station[51], operated by Uniper, although not part of any industrial cluster to date, has undertaken a carbon capture readiness assessment as part of a recent power station upgrades. This could provide NLWA with a North London partner to take forward shared $CO_2$ T&S infrastructure opportunities.

47 https://hydrogeneast.uk/study-released-highlighting-the-role-of-bacton-in-delivering-the-uks-hydrogen-and-net-zero-goals/
48 Green hydrogen is made from renewable electricity with no $CO_2$ emissions.
49 https://www.h2knowledgecentre.com/content/project379
50 Blue hydrogen is hydrogen separated from natural gas with $CO_2$ emissions captured and stored.
51 https://www.uniper.energy/company/locations/united-kingdom

# 4 Strategic Discussion – Developing a CCS Solution for the ERF

## 4.1 Overview

As mentioned in Section 2, a CCS solution involves important interdependencies with a wider CCS value chain (see Figure 1), which is explored in more detail below.

The interdependencies for a CCS solution arise between all CCS value chain partners shown in Figure 1. This is because of a need for the $CO_2$ emitting process to continue operating its main business regardless of the availability of the T&S infrastructure. Similarly, the T&S infrastructure needs to continue to receive a steady (planned) flow of $CO_2$ from its network users (the $CO_2$ emitters) for both financial and technical reasons.

If the $CO_2$ emitter or any part of T&S infrastructure has an unscheduled outage, then technical and financial issues could arise. The conditioning and temporary storage plant at the $CO_2$ emitter site, at onshore and coastal staging points, and at the point of injection to permanent storage site, all add a 'safety buffer' of time and risk mitigation against these situations.

For industrial businesses, the cost of adopting the CCS solution includes increased CAPEX to develop and construct the PCC, potentially reduced revenues from normal plant outputs (the CCS is a parasitic load on any heat and power produced) and increased OPEX to pay for the transportation and permanent storage of the captured $CO_2$.

The T&SCo invests significant CAPEX to build and operate the T&S infrastructure in the short and long-term. To justify this, they must also develop a pipeline of customer projects that will implement solutions to capture their $CO_2$ emissions and sign long-term contracts to make use of the T&SCo's assets, paying capacity/volume fees for the T&S systems use.

The CCS business models are designed to transfer/share some of these risks with government. For the T&S owner/operators and industrial product manufacturers the increased CAPEX and OPEX costs and risk is expected to be supported by government funding as described in Section 3.

These interdependencies and risks mean that strong relationships, agreements, and trust must be developed between all stakeholders concerned within the CCS solution, for instance to co-ordinate applications for funded support, and to ensure smooth running of the system once operational.

*Key consideration:* The Authority will be engaging with industry stakeholders over the coming months to identify and explore options for $CO_2$ transport solution and permanent $CO_2$ storage sites and to develop trusted relationships with relevant organisations.

## 4.2 CCS cluster formation

For energy intensive businesses remaining in the UK's industrial clusters, stakeholder grouping was supported by a government programme and made easier by the close geographic proximity to other industrial businesses and pre-existing strong working relationships. NLWA will need to search a wider area and reach outside its familiar industry contacts to establish a suitable cluster of $CO_2$ emitters to support a CCS solution for the NLHPP.

All the UK's industrial clusters are close to the coast making access to permanent $CO_2$ storage cheaper and quicker. Government has recognised that 'dispersed industry' has a harder route finding workable and cost-effective $CO_2$ transportation routes to the coast.

In 2019, the government commissioned a report 'CCS deployment at dispersed industrial sites'[52] to consider the best deployment options for ICC at dispersed sites (e.g. sites not within 30km of a major

[52] https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-deployment-at-dispersed-sites

port), with particular focus on the T&S infrastructure. The optimisation process followed and some of the principal risks and constraints related to $CO_2$ transportation options and costs are relevant to NLHPP.

*Key consideration:* The Authority will follow a similar process to identify and assess options to find the most cost-effective $CO_2$ transportation route(s) to suitable coastal sites where $CO_2$ can be permanently stored. Potential partners for NLWA in the formation of a CCS cluster will be found by mapping $CO_2$ emitters across a wide area, defined by possible $CO_2$ transport corridors between the Edmonton EcoPark site and the industrial clusters or related projects at the coastal locations.

## 4.3 Carbon capture technology solution for the ERF

For the ERF at the Edmonton EcoPark, the most likely carbon capture technology is referred to as a post-combustion carbon capture (PCC) plant because the $CO_2$ is captured from the flue gas generated after the combustion of waste. The PCC plant will take in flue gas from the ERF via a connection downstream of the flue gas treatment plant, bypassing the stack. The flue gas is cooled and may require additional treatment to remove other gases that would compete with the capture of $CO_2$, for example, sulphur oxides ($SO_x$) before it passes through an absorption column where the $CO_2$ is removed using an amine-based solvent. The treated flue gas will be directed back to the ERF for discharge to atmosphere via the stack. The captured $CO_2$ is then stripped from the amine solvent in a desorption column using steam.

Carbon capture technology has been proven at commercial scale, but further technological development of carbon capture plants is underway with scope to deliver more cost-effective and easier to install solutions. For example, Carbon Clean (a carbon capture technology provider) state that their 'next-generation' modular carbon capture technology will deliver a ten-fold reduction in equipment size, resulting in a 50% reduction in both capital investment and operational investment requirements compared to traditional open-plant designs[53]. Whereas there is less scope for cost reduction due to technology development in T&S infrastructure.

A PCC plant solution capable of capturing at least 90% of carbon emissions from the ERF needs to be designed and developed through an initial FEED study. The purpose of the initial FEED study would be to progress the concept carbon capture solution for the ERF through basic engineering and design. This would result in an outline implementation plan and show how the delivery of the solution would fit with the wider NLHPP. NLWA would also need to develop and manage the planning application and associated environmental impact assessment related to the PCC plant.

Building relationships with other CCS clusters will provide an opportunity for learning including about potential CCS solution suppliers in the market, their technology and service solutions. This could inform a CCS technology solutions options appraisal and provide cost estimates for the business case, final investment decision and eventual procurement.

*Key consideration:* NLWA will continue to monitor the technology development of PCC plant. Stakeholder engagement with the UK CCS community through membership of the Carbon Capture and Storage Association (CCSA) is considered to be beneficial to identify the right CCS solution, its design and planning and permitting application process.

## 4.4 Transport and storage approach

The development of a strategy for the CCS project at the ERF requires the formation of a partnership approach with a T&S operator. Preparation of an implementation plan will involve identification and assessment of available options to find the most cost-effective $CO_2$ T&S route for $CO_2$ arising from the ERF.

This will be achieved by mapping transport routes and energy intensive industries ($CO_2$ emitters) across a wide area, defined by the possible $CO_2$ transport corridors between the Edmonton EcoPark

[53] https://www.carbonclean.com/modular-systems

site and the industrial clusters or other relevant projects at the coastal locations. This will enable identification of potential cluster members ($CO_2$ emitters) and stakeholders for NLWA to engage with for each short-listed transport route option and coastal end point. Information collected will allow an optimal, cost-effective transport route and end point to be selected for further project development.

The nearest areas likely to provide staging points to offshore $CO_2$ transport and permanent storage for the NLHPP have been identified as:

- The Bacton Gas Terminal in Norfolk.
- The Cavendish Project at the Isle of Grain.

There are several transport modes to be considered for $CO_2$ captured from industrial sites including pipeline, road, rail or shipping. A high-level assessment suggests that road transport will not be a viable option for the ERF due to the large number of road traffic movements required.

The Edmonton EcoPark site is situated next to the Lee Navigation waterway and to the North of the River Thames. Rail lines for commuter services into London are plentiful in the area running East-West and to the North East. Some of these are shared by freight rail services, although these are constrained in their capacity due to commuter rail traffic.

There are some wayleaves surrounding rail lines and existing utilities in the area which may provide space for $CO_2$ pipework to be considered, however, a long-distance pipeline out of London and towards possible $CO_2$ cluster areas at nearby coasts is thought to be highly complex, time consuming and expensive to develop. All these options will be assessed for their potential as transport corridors.

*Key consideration:* Mapping the opportunities and constraints for a $CO_2$ transportation route out of London will enhance the options analysis and prioritisation. Identifying and meeting with other energy intensive businesses interested in CCS along these routes will enable NLWA to collate the overall opportunity for CCS and to develop a stakeholder group to pool knowledge. Together this will drive a wider ‘cluster’ approach to decarbonise North London, build a strong evidence base to support the CCS project in funding applications, and make the project more attractive to investors.

# 5 NLWA CCS Work to Date

## 5.1 Overview

The NLHPP Carbon Strategy, whose first iteration was approved by NLWA members in May 2021, commits the NLHPP to achieving a Net Zero carbon status for the operational phase of the ERF. Net zero carbon status is achieved by balancing the amount of emitted greenhouse gases with the equivalent emissions that are either sequestered or offset.

NLWA is working towards gaining a leading role in the implementation of CCS for EfW facilities by assessing the deployment of this technology at the ERF, to contribute to achieving Net Zero operational emissions for the NLHPP.

## 5.2 CCS feasibility assessment

In preparing this outline strategy, NLWA has undertaken an initial assessment of the technical, financial, and environmental parameters of PCC plant, on-site liquefaction, and intermediate storage, in addition to transport for off-site use and permanent storage. This has included liaising with key industry stakeholders, including carbon capture technology providers, who have been working with other EfW facilities across Europe.

In late 2020, NLWA brought together its technical advisors in a workshop to discuss CCUS opportunities for the ERF. This included policy enablers, potential funding and financing, potential carbon use solutions available in the UK, as well as potential options from the permanent storage of the $CO_2$. A high-level discussion on the potential business case, was also carried out, including a discussion around the potential CAPEX and OPEX, as well as any potential revenue streams.

Currently, a detailed CCS feasibility assessment is being carried out, which aims at developing a business case for implementing a CCS solution for the ERF, that is technically, financially and environmentally viable. The assessment is also determining the potential opportunities for developing a CCS cluster that the ERF would be part of. As a result, extensive stakeholder engagement has begun with relevant government bodies (e.g. BEIS), trade associations (e.g. CCSA), providers of carbon capture and liquefaction technologies, as well as investors and developers of carbon transport and permanent storage solutions.

Stakeholder engagement is the key catalyst for:

- Identifying opportunities for shared T&S infrastructure for captured $CO_2$ and relevant CCS cluster formation;
- Influencing government in the development of business models for ICC including CCS for EfW facilities, and
- Learning from the wider CCS project community.

## 5.3 Carbon Capture Readiness Assessment

In early 2021, a Carbon Capture Readiness Assessment of the ERF was carried out to understand any potential constraints in the outline design and to inform tender discussions undertaken as a part of the procurement of the ERF. The readiness assessment reviewed potential impacts on the boiler and steam cycle, flue gas cleaning requirements, additional cooling, and service requirements as well as available space.

The report concluded that there are no material reasons to suggest that it would not be technically feasible to retrofit carbon capture in the future, and once the existing EfW facility was decommissioned and deconstructed sufficient space would be available at the Edmonton EcoPark site for installation of a PCC plant.

To be suitable for carbon capture the pollutant levels within the ERF flue gas needs to be minimised as much as possible. The ERF will operate a combined wet-dry flue gas cleaning system with Selective Catalytic Reduction (SCR). This is a significant advantage as only minimal additional flue gas cleaning will be required for any future carbon capture process. Accordingly, for the ERF, one additional flue gas scrubbing column would be required, which could simply be installed as part of installation of any new PCC plant.

To implement carbon capture at the ERF a further consideration is the large amount of steam required for regeneration of the liquid solvent used to capture $CO_2$. Live steam from the steam header (foregoing some electricity production) could be used in the future for this purpose. Additional space would also be required for steam and flue gas ducts both to allow for the PCC plant to be installed but this could be accommodated in the future design of the ERF.

# 6 Forward Plan for CCS for the ERF

## 6.1 Overview

For a CCS solution to be developed for the ERF, several workstreams need to be progressed, some simultaneously. To give an indication of possible timescales for this project, the outline programme in **Error! Reference source not found.** was developed.

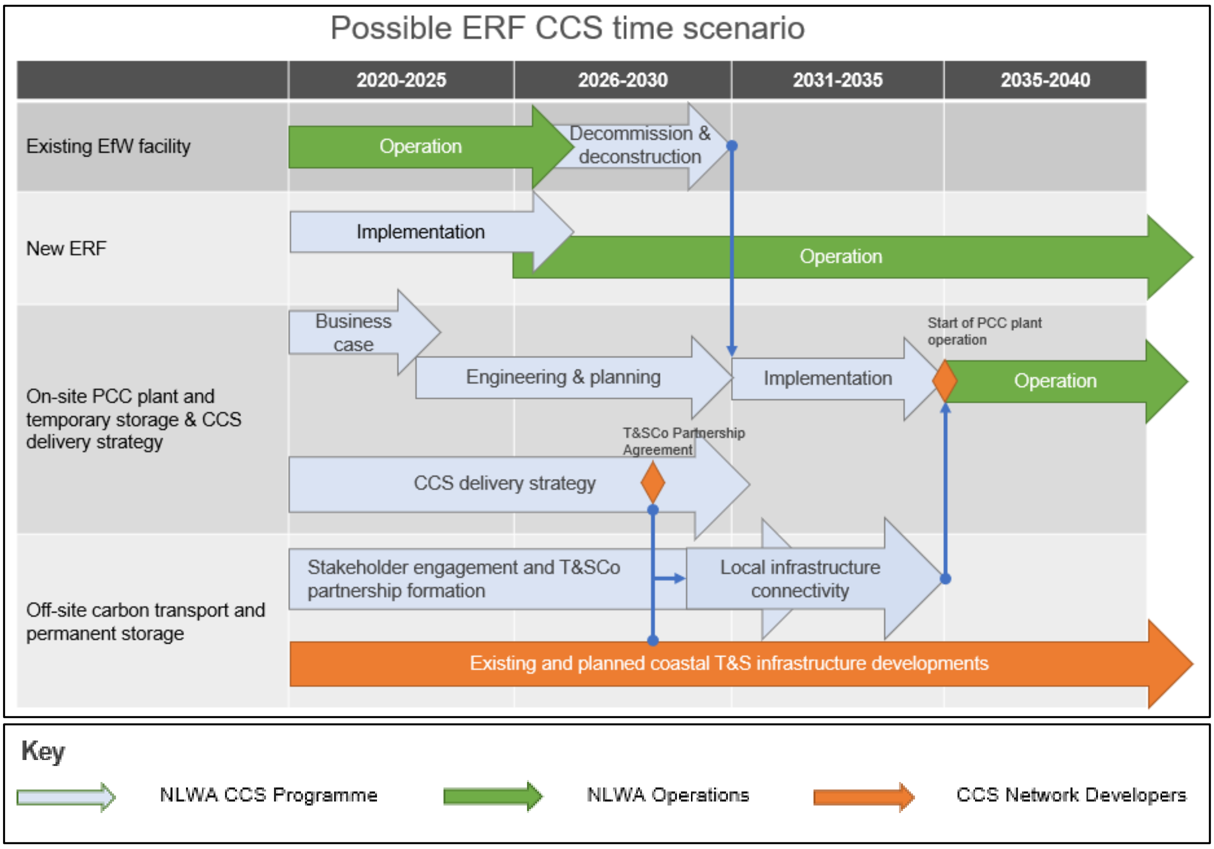


*Figure 4: Possible ERF carbon capture and storage time scenario*

The existing EfW facility will be decommissioned and demolished when the new ERF is fully operational (expected to be around the end of 2025). The existing EfW facility is expected to be fully decommissioned and demolished by 2030 freeing up space in the centre of the EcoPark for other uses such as carbon capture.

As shown in Figure 4: Possible ERF carbon capture and storage time scenario a delivery strategy and business case for the CCS solution will be developed in parallel. The associated technical engineering and planning activities related to the CCS solution are expected to be completed by 2030. Authority decisions on the use of the space left following demolition of the existing EfW will be sought prior to implementation activities.

Following a period of implementation, it is possible for a post-combustion carbon capture plant (PCC) to be operational at the EcoPark by around 2035. However, the successful implementation and operation of any PCC plant will greatly depend on available funding and financing as well as the establishment of a suitable T&S network connection for the ERF, and the securing of the appropriate planning and permitting consents.

Further significant stakeholder engagement will be required with relevant CCS T&SCo developers and operators as well as other CCS cluster members with the intention of CCS partnership formation and finalisation of the T&S routing from the Edmonton EcoPark site to a coastal staging location and transport to a permanent storage site.

T&SCo infrastructure developments (shown in orange), such as subsea pipelines and $CO_2$ storage repurposing, may have been underway for some time and other projects may have provided the $CO_2$ anchor loads for the T&S infrastructure to be developed originally.

Once a T&SCo ‘Partnership Agreement’ has been signed, implementation of the CCS solution can start, which is assumed to be completed by 2035. This is likely to involve the development of some local $CO_2$ intermediate transport infrastructure, for example, a local $CO_2$ pipeline.

## 6.2 Delivery strategy

The delivery strategy will be progressed through a mapping exercise and options assessment and ongoing and extensive stakeholder engagement. The mapping and options assessment will establish possible coastal staging points for offshore permanent $CO_2$ storage and the possible routes from the Edmonton EcoPark site to these locations. Energy intensive businesses near these routes will be identified and mapped as potential stakeholders for creation of a CCS cluster to share intermediate transport with. This mapping work is already underway with a good range of local stakeholders mapped in London and surrounding areas.

NLWA will engage with stakeholders identified during the mapping in order to collate data about $CO_2$ emissions, assets and land ownership. This will be added to the mapping to inform the options analysis and prioritisation.

NLWA and its advisers have started to identify potential stakeholders and projects with a view to determining the feasibility of creating a CCS cluster. Research into the industrial $CO_2$ emitters in the area indicates that there are some major $CO_2$ emitters, which could benefit from forming a CCS cluster including:

- Existing power stations such as Enfield Combined Cycle Gas Turbine (CCGT) (Uniper), North Grain CCGT (Uniper), Medway Power (SSE Thermal), Damhead Creek (Vitol) and Coryton (Intergen) currently emit over 7 million tonnes $CO_2$ per year in total.
- The planned Project Cavendish blue hydrogen production facility on the Isle of Grain will capture the $CO_2$ from the production process. Initially, this will be around 1.3Mt$CO_2$/year increasing to around 3.3 million tonnes $CO_2$ per year for the next phase, with $CO_2$ initially proposed to be shipped to a third-party storage location.

The total $CO_2$ emissions from the above-mentioned sources alone are around 10 million tonnes $CO_2$ per year, which would justify the establishment of a cluster.

Initial research has identified that the Cavendish project will initially ship $CO_2$ to one of several possible sites for permanent storage, but that in the longer term, business plans could justify the development of an offshore pipeline solution to a geological storage site in the Southern North Sea.

The Hydrogen East project as assessed the Bacton Gas Terminal in East Anglia for its potential to develop a coastal staging point to $CO_2$ storage and confirmed that it has a number of candidate pipelines and permanent storage sites available in the Southern North Sea.[54] The 2016 ‘Strategic UK $CO_2$ Storage Appraisal Project Selected Site Inventory’, indicates suitable $CO_2$ storage locations of depleted oil and gas fields in the Southern North Sea, along with their capacities including Hewett (circa 206 million tonnes $CO_2$), Bunter36 (circa 280 million tonnes $CO_2$), Viking A (circa 130 million tonnes $CO_2$) and Endurance (circa 530 million tonnes $CO_2$).

The possible intermediate $CO_2$ transport options, routes to these developing coastal staging points and available permanent storage sites will be reviewed over the coming months to test their feasibility

[54] https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal

and to inform the development of a loose CCS cluster which will justify and share the joint T&S infrastructure.

## 6.3 Engineering and planning

Based on these figures, and making use of stakeholder's experience with CCS solution providers elsewhere the CCS technical design and implementation planning will be developed.

It is envisaged that the on-site carbon capture, conditioning, compression (liquefaction), and temporary storage infrastructure will be installed at the area which is currently occupied by the existing EfW facility.

The construction and installation works related to the PCC plant could only begin when the existing EfW facility is decommissioned and deconstructed by the end of 2030. Funding discussions will be undertaken with BEIS for Track 2 and Track 3 CCUS sequencing (which may be available at the end of the Track 2 funding, which ends in 2030). However, the exact deployment timeline is also being considered as part of the detailed CCS feasibility assessment.

The deployment timeline is dependent on available funding and financing, on-site space availability for carbon capture plant retrofitting, and for the installation of liquefaction and temporary captured $CO_2$ storage infrastructure. It is also dependent on the establishment of a suitable T&S network connection for the ERF, and the securing of the appropriate planning and permitting consents.

Apart from ensuring that any chosen transport route is financially and technically viable in the long-term, NLWA will also ensure that its environmental impacts are small, and that the $CO_2$ emissions associated with transport, are not detrimental to the overall carbon footprint of the ERF and its CCS solution.

# 7 Future Decisions for CCS Deployment for the ERF

## 7.1 Space allocation at the Edmonton EcoPark

Critical to ensuring that CCS can be delivered for the NLHPP is to safeguard sufficient space for a PCC plant at the Edmonton EcoPark site. It is envisaged that the most suitable space for installing the required PCC plant is at the location currently occupied by the existing EfW facility. As stated above, this facility is planned to be deconstructed by the end of 2030, once the ERF is commissioned and fully operational.

It is estimated that the freed-up space from the deconstruction of the existing EfW facility will comprise an area of approximately 35,000m$^2$. The ongoing CCS feasibility assessment for the ERF indicates that for 700,000 tonnes $CO_2$ per year to be captured an area of approximately 14,000m$^2$ would be needed.

**Error! Reference source not found.** shows the proposed location of the PCC plant and approximate footprint requirement. The proposed location for the PPC plant immediately south of the ERF is considered most suitable because the connecting pipework for steam and flue gas to the ERF can be more easily installed without major disruptions to the rest of the Edmonton EcoPark site.

The PCC plant footprint requirements will be further refined once a decision is made on the most suitable transport method for the captured carbon, as different transport methods will require different on-site storage arrangements.

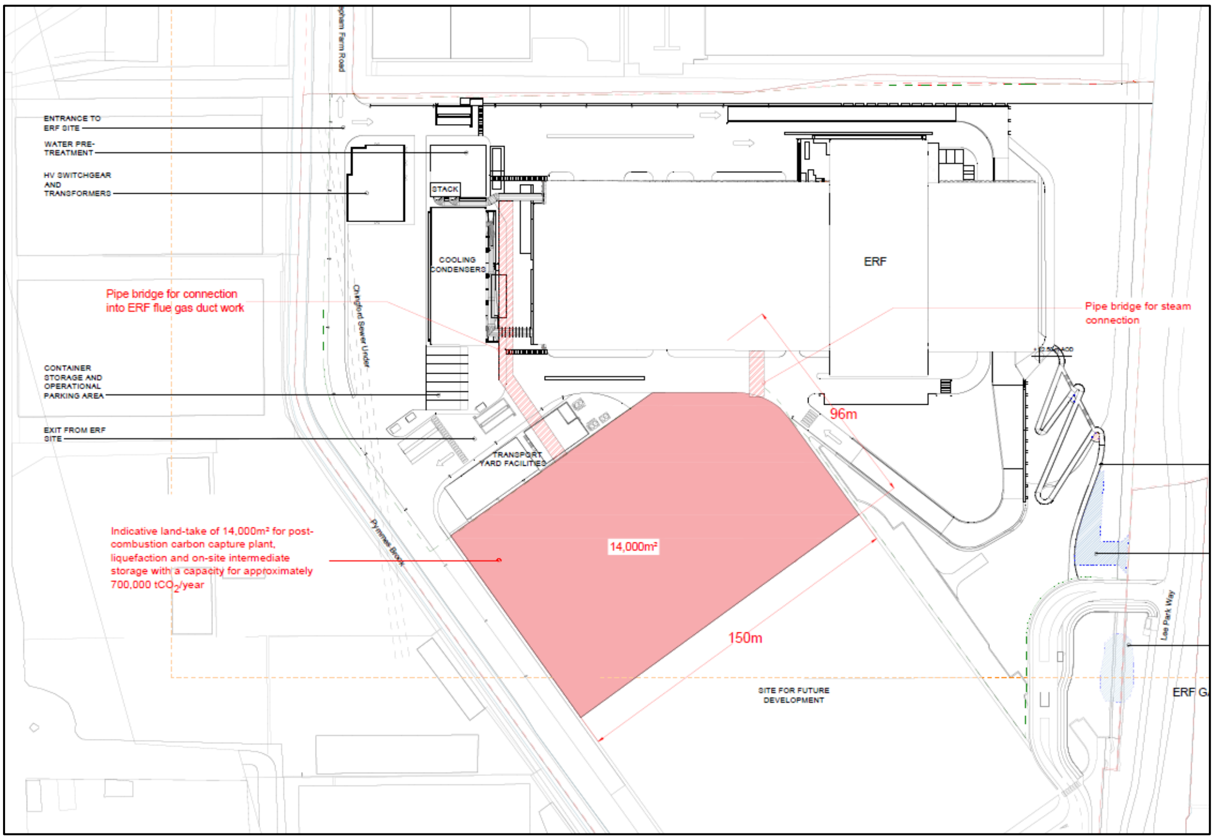


*Figure 5: Indicative layout a 700,000 t$CO_2$/year PCC plant and associated footprint of approximately 14,000m$^2$*

## 7.2 Business case

A suitable business case is being developed as part of the ongoing CCS feasibility assessment for the NLHPP. For decisions to be made on business case, the following steps are being taken:

1. Review and benchmarking of costing information for on-site equipment (carbon capture, liquefaction, on-site temporary storage), off-site transport, use and permanent storage. This information will help to determine CAPEX and OPEX and funding requirements.
2. Review of potential revenue streams. Such revenue streams may include carbon certificate trading income, $CO_2$ sales (e.g. to other industries as part of CCU), and any income from use of CCS infrastructure by third parties (e.g. use of any transport infrastructure developed by NLWA). Any potential revenue streams are subject to decisions being made on several aspects, such as:
    - The most suitable T&S infrastructure for the captured $CO_2$;
    - Any agreements to incorporate CCU options for part of the captured $CO_2$ (in addition to permanent storage), for example, if the ERF is part of a CCUS cluster, making the availability of CCU options more likely; and
    - Any available opportunities and decisions made with regards to carbon emissions trading (i.e. from capturing biogenic carbon).
3. Use of BEIS guidance; particularly, their proposed commercial frameworks for T&S, power, and ICC business models.
4. Review of potential business models to develop a business case, whose underpinning rationale will be driven by an evaluation of strategic (i.e. is it a good fit for strategic and business needs), commercial (i.e. is it commercially viable throughout the project lifecycle), economic (i.e. does it optimise value for money), financial (i.e. is it affordable based on available funding and financing) and management (i.e. is it achievable and can it be successfully delivered) criteria.

## 7.3 Planning and permitting

Specific planning requirements are largely dependent on defining the on-site CCS infrastructure solution to be developed, and the stakeholders involved in funding, developing, and ultimately operating this infrastructure. Therefore, specific planning arrangements will be pursued once the business case is established, which is currently being assessed and developed as part of the CCS feasibility assessment.

As part of obtaining planning permission for the PPC plant, it is expected that an environmental impact assessment will be carried out, to ensure that any significant environmental effects, as well as health impacts associated with developing the PCC plant solution, will be identified and mitigated.

In England and Wales, PCC infrastructure installations for power stations, including EfW facilities, like the ERF, are permitted under the Environmental Permitting Regulations (England and Wales) 2016 (as amended).

According to the Environment Agency, for environmental permitting purposes, PCC plant is a Part A (1) 6.10 activity in its own right when the $CO_2$ is being captured for geological storage (i.e. permanent storage). However, it could be directly associated with a combustion activity installation when the $CO_2$ is captured and used for other purposes (i.e. CCU).

It is expected that the existing environmental permit for the ERF (EPR/UP3232AC/V002), would undergo a variation for the installation of the PCC plant infrastructure. Carbon capture readiness is a requirement imposed on thermal plants to enable future capturing and storing of carbon following a plant upgrade.

To demonstrate carbon capture readiness, a relevant statement will be produced as part of the environmental permit variation application, following the UK government's most updated carbon capture readiness guidance.

A separate environmental permit application will need to be prepared for the PCC plant itself and its associated infrastructure, as per Environment Agency guidance. It will be ensured that in preparation for the environmental permit application, the proposed PCC plant solution will undergo a 'Best Available Techniques' review in line with the Environment Agency's 'Post-combustion carbon dioxide capture: best available techniques (BAT)'[55] guidance.

The Environment Agency's guidance covers both new plants and retrofits to existing power plants. The guidance identifies environmental issues to address. It includes, among others, the requirement to complete an assessment to demonstrate plant adaptation to climate change risks.

Preparation of any environmental permit or permit variation applications is subject to completion of the ongoing CCS feasibility assessment, which will determine the business case and proposed deployment timeline for the CCS solution of the ERF.

As stated above, NLWA is engaging closely with the ERF tenderer as part of the ongoing ERF procurement process, in order to ensure that carbon capture readiness requirements are included in the design development of the ERF.

[55] Post-combustion carbon dioxide capture: best available techniques (BAT) - GOV.UK (www.gov.uk)

# 8 Summary and Key Points

There is clear evidence that CCS is essential in a transition to Net Zero by 2050, and new support for the waste industry to benefit from this technology with strong government backing and funding. NLWA will drive the development of CCS at the Edmonton EcoPark site to further improve the sustainability credentials of the NLHPP, and contribute to local climate action.

The government has committed in its ‘Ten Point Plan for a Green Industrial Revolution’ to have two CCS cluster projects operational by 2027 (Track 1), and a further two by 2030 (Track 2). NLWA will engage with government to determine the process, timelines, eligibility, and evaluation criteria of projects for Track 2 CCUS sequencing, and future government funding arrangements beyond 2030 (Track 3).

This includes engaging with government to influence policy on emerging business models for EfW-CCS and exploring funding options for capital investment and operation of the PCC plant. In addition, NLWA will engage with other stakeholders including carbon emitters, CCSA, and industrial CCUS cluster projects to transfer knowledge and lessons learnt.

NLWA is at the forefront of considering the feasibility of an affordable CCS solution for the ERF aiming to develop a shared infrastructure solution with the necessary stakeholders for T&S to reduce the investment risk and make the project bankable.

This includes further feasibility study work to identify potential collaborators to develop a joint solution for T&S infrastructure. We are using a digital carbon mapping tool considering a strategic solution for a CCS cluster. This additional feasibility study work will also consider technical, financial, and environmental constraints and opportunities for a CCS solution.

Building a trusted relationship with a credible and technically feasible T&SCo is a priority for this outline CCS strategy.

NLWA has undertaken a carbon capture readiness assessment for the ERF. The report concluded that there are no material reasons to suggest that it would not be technically feasible to retrofit carbon capture in the future, and once the existing EfW facility was decommissioned and deconstructed.

There is sufficient space at the Edmonton EcoPark site for a PCC plant once the existing EfW facility has been decommissioned and deconstructed.

CCU is not considered to form a major part of the overall carbon capture solution for the ERF as the overall demand for $CO_2$ in the UK (e.g. food and drink industry) is relatively small (approximately 600,000 $tCO_2$ per year) compared to the quantity of $CO_2$ from the ERF (approximately 700,000 $tCO_2$ per year).

## APPENDIX A: GLOSSARY AND ABBREVIATIONS

| Abbreviation | Meaning |
|---|---|
| BECCS | Bioenergy with carbon capture and storage |
| BAT | Best Available Techniques |
| BEIS | The Department for Business, Energy & Industrial Strategy |
| CAPEX | Capital expenditure |
| CCC | Committee on Climate Change |
| CCGT | Combined Cycle Gas Turbine |
| CCU | Carbon capture and utilisation |
| CCUS | Carbon capture use and storage |
| CCS | Carbon capture and storage |
| CCSA | Carbon Capture and Storage Association |
| CIF | CCS Infrastructure Fund |
| $CO_2$ | Carbon dioxide |
| DACCS | Direct Air Carbon Capture & Storage |
| DPA | Dispatchable Power Agreement |
| EfW | Energy from waste |
| ERF | Energy recovery facility |
| EU | European Union |
| FEED | Front end engineering design |
| ICC | Industrial Carbon Capture |
| IEA | International Energy Agency |
| LCH | Low Carbon Hydrogen |
| NLHPP | North London Heat and Power Project |
| NLWA | North London Waste Authority |
| NOK | Norwegian krone currency |
| OGA | Oil and Gas Authority |
| OPEX | Operational expenditure |
| PCC | Post-combustion carbon capture |
| RAB | Regulated asset base |
| SCR | Selective Catalytic Reduction |
| $SO_x$ | Sulphur oxides |
| T&S | Transport and storage |
| T&SCo | A company licensed to provide transport and storage services |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US | United States |