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Enabling net zero: progress on deploying CCS to decarbonise UK industrial clusters

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Acronym	Definition
Bioenergy CCS (BECCS)	Refers to the process of extracting bioenergy from biomass and capturing and storing the carbon, thereby removing it from the atmosphere
Capital Expenditure (CAPEX)	Funds used by a company to acquire, upgrade, or maintain capital assets such as property, plants, buildings, technology, or equipment
Carbon Border Adjustment Mechanism (CBAM)	This is a mechanism implemented by governments to account for the carbon cost of producing imported goods
Climate Change Committee (CCC)	An independent statutory body established to advise the UK and devolved governments on GHG emission targets and report to Parliament on progress made in reducing emissions and preparing for and adapting to the impacts of climate change
Carbon Capture and Storage (CCS)	The process of capturing CO_2 from industrial processes, power generation, and other sources of CO_2. The captured CO_2 is then stored permanently in disused oil and gas fields or naturally occurring geological storage sites
Carbon Capture and Storage Association (CCSA)	Organisation that represents the interests of companies and organisations seeking to develop commercial-scale CCUS projects in the UK, EU, and internationally
Carbon Capture, Utilisation and Storage (CCUS)	The process of capturing CO_2 from industrial processes, power generation, and other sources of CO_2. The captured CO_2 is then either used, for example in chemical processes, or stored permanently in disused oil and gas fields or naturally occurring geological storage sites
Combined Heat and Power (CHP)	The use of a heat engine or power station to mainly generate electricity and useful heat at the same time with moderate efficiency
CCS Infrastructure Fund (CIF)	A fund announced in 2020 that supports capital expenditure on transport and storage networks and industrial carbon capture (ICC) projects
Commercial Operations Date (COD)	The date on which the facility achieves commercial operation following commissioning
Development Consent Order (DCO)	A statutory order which provides consent for the project and means that a range of other consents, such as planning permission and listed building consent, will not be required
Department for Energy Security and Net Zero (DESNZ)	Ministerial department responsible for delivering security of energy supply, ensuring properly functioning energy markets, encouraging greater energy efficiency, and seizing the opportunities of net zero to lead the world in new green industries
Development Expenditure (DEVEX)	Costs associated with the development of the project and associated with pre-FID activities such as engineering design, licensor technology fee, and survey costs for permitting activities
Department for Housing, Communities and Local Government (DHCLG)	Ministerial department responsible for fixing the foundations of an affordable home to handing power back to communities and rebuilding local governments
Dispatchable Power Agreement (DPA)	Business model designed to incentivise generators to capture and store carbon which would historically be emitted and support power generation with CCS
Environment Agency (EA)	An executive non-departmental public body, sponsored by the Department for Environment, Food & Rural Affairs, responsible for regulating major industry and waste, treatment of contaminated land, water quality and resources, fisheries, inland river, estuary and harbour navigations, and conservation and ecology
Equity, Diversity, and Inclusion (EDI)	A conceptual framework that promotes the fair treatment and full participation of all people, especially populations that have historically been underrepresented or subject to discrimination because of their background, identity, disability, etc
Engineering, Procurement and Construction (EPC)	Refers to the detailed engineering, procurement and construction phase of the project. Activities associated with this phase are detailed design, procurement of equipment or materials, construction and commissioning
Emissions Trading Scheme (ETS)	Refers to a "cap and trade" scheme where a limit is placed on the right to emit specified pollutants over an area and companies can trade emission rights within that area
Fluid Catalytic Cracking (FCC)	A type of secondary unit operation, which is primarily used in producing additional gasoline in the refining process

Acronym	Definition
Front End Engineering Design (FEED)	Refers to the front-end engineering design phase of the project, executed prior to the FID stage gate
Final Investment Decision (FID)	A common term used in reference to the last step of determining whether to sanction the construction of an infrastructure project
Full Time Equivalent (FTE)	A measure of employment level, typically based on an established definition of the number of hours worked over a given period to be considered a full-time employee (e.g., 40 hours a week, 52 weeks a year)
Great British Energy (GBE)	Publicly owned energy company, designed to drive clean energy deployment, boost energy independence, create jobs, and ensure UK taxpayers, billpayers and communities reap the benefits of clean, secure, home-grown energy
Greenhouse Gas (GHG)	Gases that cause global warming when emitted to the atmosphere. They include CO2, methane, and others as set out in the Kyoto Protocol
Gross Value Added (GVA)	The value generated by any unit engaged in the production of goods and services
His Majesty's Treasury (HMT)	Government's economic and finance ministry, maintaining control over public spending, setting the direction of the UK's economic policy, and working to achieve strong and sustainable economic growth
Hydrogen Production Business Model (HPBM)	A business model that is intended to incentivise the production and use of low carbon hydrogen through the provision of revenue support to overcome the cost gap between low carbon hydrogen and higher carbon counterfactual fuels
Health and Safety Executive (HSE)	The UK's national regulator for workplace health and safety
Industrial Carbon Capture (ICC)	A business model that is intended to incentivise the adoption of carbon capture technology by industrial users who have few other options to achieve deep decarbonisation
Industrial Decarbonisation Challenge (IDC)	Challenge programme that supports development of low carbon technologies and infrastructure, increasing industry competitiveness and contributing to the UK's clean growth
Industrial Decarbonisation Research and Innovation Centre (IDRIC)	Research and innovation centre powered by research and innovation & funded by UKRI to develop innovative decarbonisation solutions at pace and scale in the places where it matters most
Low Carbon Hydrogen Production (LCHP)	Business model that will provide revenue support to hydrogen producers to overcome the operating cost gap between low carbon hydrogen and high carbon fuels
Million tonne per annum (MTPA)	A commonly used weight-based metric.
National Infrastructure Commission (NIC)	Executive Agency of the HM Treasury, providing government with impartial, expert advice on major long term infrastructure challenges
Non-Pipeline Transport (NPT)	The transportation of CO_2 through road, rail and shipping modes of transport.
Natural Resources Wales (NRW)	Welsh Government Sponsored Body that focusses on tackling the climate, nature and pollution emergencies
Nationally Significant Infrastructure Project (NSIP)	Project that is dealt with under the Planning Act 2008 and was introduced to streamline the consenting process for big infrastructure schemes as well as make it fairer and faster for local communities and applicants
North Sea Transition Authority (NSTA)	An executive non-departmental public body, sponsored by the Department for Energy Security and Net Zero to regulate and influence the oil and gas, offshore hydrogen, and carbon storage industries
National Wealth Fund (NWF)	A UK fund that will address the current funding gap for green investment projects that are not funded by private investors
Operating Expenditure (OPEX)	Expense that a business incurs through its normal business operations

Acronym	Definition
Scottish Environment Protection Agency (SEPA)	Scotland's principal environmental regulator, protecting and improving Scotland's environment
Science, Technology, Engineering and Mathematics (STEM)	An approach to education that focuses on the hard sciences, develops critical thinking skills, and improves problem-solving abilities
Transport and Storage (T&S)	Defined as Transport and Storage company in the UK business models
Transport and Storage Regulatory Investment (TRI)	A business model that is based on the successful regulated asset base model. It has three key objectives: to attract investment in the T&S network to establish a new CCUS sector; enable low-cost decarbonisation in multiple sectors; and develop a market for carbon capture
UK Research and Innovation (UKRI)	National funding agency investing in science and research in the UK

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Foreword

The United Kingdom (UK) is committed to meeting net zero. This commitment will result in the UK economy becoming stronger and more competitive, revitalising industrial communities along the way and upskilling the workforce for the jobs of the future.

With just over twenty-five years until 2050, we find ourselves with challenges and uncertainty, but also an achievable path forward. The UK must accelerate emissions reductions across all sectors of the economy to meet its legally binding net zero target. Industrial emissions, with their hard-to-abate, energy-intensive processes, present a particular challenge.

As underscored by the Climate Change Committee (CCC), Carbon Capture and Storage (CCS) is 'a necessity, not an option' for the transition to net zero[1], and is one of the technology solutions required for the UK's journey to net zero emissions. Therefore, it is my privilege to present *Enabling net zero: progress on deploying CCS to decarbonise UK industrial clusters* (the Report), a report that outlines the challenges faced, and insights gained from the Industrial Decarbonisation Challenge (IDC) Deployment Projects which are striving to deliver CCS and low carbon hydrogen at scale in the UK. The recommendations in this report will support future CCS and low carbon hydrogen rollout initiatives.

Establishing at least four low carbon industrial clusters by 2030 and the world's first net zero cluster by 2040 relies not only on rapid deployment of first-of-a-kind projects but also widespread scale up of cost-effective decarbonisation across the UK. The Report's practical insights and actionable recommendations lay the foundation for scalable CCS and low carbon hydrogen. The journey to industrial decarbonisation will follow several steps from conceptual and preliminary design towards a positive Final Investment Decision (FID), and then through the construction phase into commercial operation.

My hope is that the projects selected through the IDC will successfully deliver the first CCS and low carbon hydrogen projects in the UK, cement the UK's reputation as a world leader in industrial decarbonisation, and yield benefits for all.

Dr. Bryony Livesey

Dr. Bryony Livesey
IDC, Challenge Director – UK Research and Innovation

September 2024

Executive Summary

The necessity of carbon capture and storage for decarbonising UK industry

The UK recognises the urgency and necessity of reducing greenhouse gas (GHG) emissions to address climate change as the defining challenge of our time. The UK was the first major economy to establish a legally binding target of net zero emissions by 2050 and to halve its emissions between 1990 and 2022[2]. Eliminating the other half will require successfully decarbonising all sectors of the economy, including industry.

The industrial sector accounted for 14% of the UK's GHG emissions in 2022[3]. The CCC notes that the deployment of CCS infrastructure is 'a necessity, not an option' for decarbonising UK industry[1]. CCS will therefore play a critical role in ensuring that the UK decarbonises, not deindustrialises.

Developing the UK's CCS and low carbon hydrogen sector

CCS deployment in industrial clusters is the key to industrial decarbonisation and wide-scale roll-out of CCS in the UK. It can also enable low carbon blue hydrogen production, which has multi-sector applications including fuel switching in industry. The co-location of over half of the UK's industrial emissions in industrial clusters presents an opportunity to use shared infrastructure for efficient and cost-effective decarbonisation. Successful deployment provides the foundation for decarbonising remaining industrial emissions.

To incubate scalable industrial decarbonisation solutions, UK Research and Innovation (UKRI) launched the IDC in 2019. Over the subsequent five years, the IDC provided £210 million towards the Government's goal to deliver four low carbon clusters by 2030 and the world's first net zero cluster by 2040. This was matched by £261 million from industry partners. Most of this funding helped advance nine first-of-a-kind industrial decarbonisation projects: IDC Deployment Projects. The IDC Deployment Projects lay the foundation for wide-scale CCS and low carbon hydrogen rollout across the UK. Once built, these projects will demonstrate the scale-up of low carbon technologies and will provide critical shared transport and storage infrastructure for emitters seeking to decarbonise via CCS or hydrogen.

Through their development journeys to date, these IDC Deployment Projects have learned valuable lessons that can accelerate the delivery of future projects in the UK and abroad. *Enabling net zero: progress on deploying CCS to decarbonise UK industrial clusters* compiles practical insights from these first-of-a-kind projects for project developers, government stakeholders, and investors who seek to advance CCS and low carbon hydrogen solutions.

This report highlights the planned contributions of the nine IDC Deployment Projects toward the UK's net zero goals, the challenges they have faced in development, and the lessons learnt so far. It sets out the next steps needed to support CCS and low carbon hydrogen projects in advancing to a positive FID and to support the Government's ambition to establish a UK CCS sector by 2030.

IDC Deployment Projects deliver environmental, economic, and social benefits

The IDC Deployment Projects are the core of the UK's industrial cluster decarbonisation strategy. They are fundamental for achieving the UK's CCS and low carbon hydrogen goals, which are stepping stones to net zero by 2050.

By 2030, the IDC Deployment Projects have the potential to:

- deploy four low carbon (CCUS) clusters[i].
- capture up to 11 million tonnes per annum (MTPA) of CO_2 by 2030, representing 55% of the UK's lower limit CCS goal of 20 MTPA.
- contribute up to 0.6 GW of low carbon hydrogen by 2030, representing 12% of the UK's non-green hydrogen production goal of 5 GW[ii].

The environmental impacts are greater still when considering additional low carbon projects enabled by the shared infrastructure developed by the IDC Deployment Projects.

While the IDC Deployment Projects are making significant progress towards net zero, they also have the potential to deliver wider economic and societal benefits across the value chain. They are in a prime position to:

- catalyse clean growth and drive investment into UK industry.
- protect jobs in the UK's industrial heartlands and develop a skilled workforce ready for a low carbon economy.
- enhance energy security through the delivery of low carbon power.
- pioneer CCS and hydrogen applications at scale.
- advance long-term economic opportunities for international trade through CO_2 import or hydrogen export prospects.

Recommendations to enable CCS deployment in the UK

To realise these benefits, the UK must take additional steps to support the IDC Deployment Projects and to develop a sustainable and competitive CCS market. The Report makes the following recommendations:

Recommendation 1: Provide clear and well-communicated market signals to drive the long-term viability and sustainability of the developing CCS and low carbon hydrogen markets

The development of a CCS market is crucial for the wide-scale rollout of CCS needed to meet the UK's 2050 net zero goal. Given the nascent state of the market, clear and well communicated

i The IDC Deployment Projects could exceed this goal if the SWIC project timeline could be accelerated to 2030, noting the Government's ambition to deliver clean power by 2030.

ii UK 2030 5 GW hydrogen production goal (which may be blue hydrogen enabled by CCS).

signals from the Government on both its short-term approach to sequencing early CCS projects and long-term strategy for developing a mature CCS market are necessary to accelerate project and capital deployment. Similarly, the supply chain requires these signals to encourage scale up of capacity to support the upcoming low carbon project pipeline. These clear and well-communicated signals are essential to de-risk projects as they move through the development lifecycle and to support the growth of the CCS market.

Recommendation 2: Address business model gaps, offer pre-FID investment coverage, and balance risk allocation to drive greater investor and developer certainty for current and future CCS and low carbon hydrogen projects

Significant private capital is necessary for large-scale CCS deployment. While private sector investment opportunities in the CCS sector are promising, the current risk profiles of projects mean government subsidy support is required. Business models have been developed to provide coverage for the risks project investors are unwilling to take. However, gaps remain for CO_2 shipping and hydrogen transport and storage. Addressing these business model gaps and providing pre-FID coverage for developers to secure schedule-critical long lead items will offer investors the confidence they need to deploy capital in the short term. As the CCS market continues to mature, ongoing consultation with market participants is needed to ensure the balance of risk is calibrated appropriately across the value chain.

Recommendation 3: Ensure that permitting is fit for purpose to meet critical delivery timelines and achieve net zero ambitions

Permitting is a significant obstacle for infrastructure projects of this size and complexity. Securing approvals through the Development Consent Order (DCO) process is time-consuming and subject to delays due to the resource constraints of regulatory bodies. Early decisions on system architecture required in permitting applications limit scope adaptations, such as the ability to accommodate new emitters. In addition, variations in the processes and requirements across England, Wales, and Scotland create complexity. Simplifying and harmonising regulatory processes and closing resource and knowledge gaps at planning bodies will deliver a fit for purpose permitting regime that can bring CCS and low carbon hydrogen projects online at the timescales required. Such process improvements would also benefit the wider low carbon infrastructure project pipeline.

Recommendation 4: Support within cluster coordination and collaboration across the value chain to drive the transition to a sustainable CCS market

From sequencing and aligning work packages to progressing an integrated FID across the CCS value chain, the level of coordination across numerous partners to deliver new capture, transport, and storage infrastructure is daunting. Most of these partners are also new to the CCS sector. Evaluating technology solutions, developing offtake and transportation agreements, navigating the Government's cluster sequencing process, and other crucial project decisions is a steep learning curve. For the UK to develop infrastructure at the pace needed to meet its net zero goals, subsequent projects must learn quickly. Establishing a publicly run knowledge sharing hub where CCS market participants can share lessons learnt and collaborate on CCS market development will increase the efficiency of deployment as the CCS market matures. Collating and formalising the best practices observed throughout the IDC process can improve coordination for future projects, building on insights captured in this report.

Maintaining momentum

As the IDC Deployment Projects, and those that follow, begin to break ground, their impact will encompass more than their contribution to industrial decarbonisation. They bring the opportunity to drive equitable growth and pursue a just transition to net zero. While the nine IDC Deployment Projects have made substantial strides in their progress towards FID, the hard work is just getting underway. Impacts will not be fully realised until projects are built and operational.

The four recommendations in the Report are based on lessons learnt from the IDC Deployment Projects and seek to address the most pressing challenges facing the UK's emerging CCS and low carbon hydrogen markets. Enacting these recommendations will pave the way for the UK to be a world-leading CCS market. Partnership between the Government and industry will be crucial to their successful execution, with the IDC continuing to champion the establishment of a Cluster Advocate body. This body would play a pivotal role in overseeing the delivery of the recommendations and actively driving them forward, thereby translating the recommendations into concrete outcomes.

1

Recommendation 1:

Provide clear and well-communicated market signals to drive the long-term viability and sustainability of the developing CCS and low carbon hydrogen markets

Sub-recommendations:

1.1 Communicate transparently and more regularly to the market on the timelines and implementation approach of the cluster sequencing process and the long-term strategy on CCS and hydrogen

1.2 Publish finalised business model terms from Track-1 process

1.3 Strengthen visibility into the national and regional pipeline of projects to UK supply chains to encourage them to ramp-up and meet upcoming demand

1.4 Evaluate how to best implement UK content targets to capitalise on the economic benefit of low carbon projects

1.5 Adjust carbon pricing policy to create an attractive environment for UK CCS investment, supporting the transition towards a self-sustaining market

2

Recommendation 2:

Address business model gaps, offer pre-FID investment coverage, and balance risk allocation to drive greater investor and developer certainty for current and future CCS and low carbon hydrogen projects

Sub-recommendations:

2.1 Develop and finalise business models coverage for hydrogen transport and storage and CO_2 shipping to enable projects that rely on them to advance

2.2 Develop a limited notice-to-proceed mechanism to enable projects to secure schedule-critical long lead items ahead of the FID stage gate

2.3 Adjust risk allocation within future iterations of the business models to re-balance in line with increasing market maturity

3

Recommendation 3:

Ensure that permitting is fit for purpose to meet critical delivery timelines and achieve net zero ambitions

Sub-recommendations:

3.1 Revamp the permitting and planning statutory process to simplify, improve or streamline it for future low carbon infrastructure projects

3.2 Continue to build up internal capacity and competencies across the regulatory bodies to facilitate timely and thorough review of low carbon projects

3.3 Allow more scoping flexibility within the DCO or equivalent planning processes to better accommodate the evolving requirements of CCS and low carbon hydrogen projects

3.4 Explore opportunities to harmonise the planning processes and requirements across England, Wales, and Scotland to facilitate rollout of cross-border low carbon projects

4

Recommendation 4:

Support within cluster coordination and collaboration across the value chain to drive the transition to a sustainable CCS market

Sub-recommendations:

4.1 Establish a publicly run knowledge sharing hub where CCS market participants can share lessons learnt and collaborate on CCS market development

4.2 Define a best practice model for intra- and inter-cluster orchestration that ensures strong leadership, collaboration along the value chain, and knowledge sharing practices

4.3 Develop a standardised approach and template for creating offtake and transportation agreements

Introduction

Net zero emissions must be achieved

Global warming is one of the biggest challenges facing the planet, requiring coordinated effort and investment from governments, industry, and wider society. Immediate action must be taken to halt the rise in global temperatures and ensure future generations can live on a sustainable planet[4]. The UK recognises the gravity of the challenge and the scale of action required, having committed to achieving net zero GHG emissions by 2050.

The UK's industrial emissions are a focal point for reduction. They account for approximately 14%, or 78 $MtCO_2e$, of the UK's total GHG emissions[3]. To meet 2050 net zero commitments, the Government indicated in 2021 that industrial emissions will need to fall by at least 90% by 2050 compared to 2021 emissions[5]. This is easier said than done. Industrial activities in sectors like refineries, chemicals, power, steel, and cement are energy-intensive and require solutions beyond energy efficiency, operational efficiency, and electrification to decarbonise.

The Industrial Decarbonisation Challenge

To support industrial decarbonisation, the IDC was established in 2019 as part of UKRI's Industrial Strategy Challenge Fund. The IDC focused on the UK's industrial clusters, which are areas where there is a concentration of co-located industries. The IDC ran until March 2024, with the principal objectives to drive scalable industrial decarbonisation solutions, namely:

1. enable detailed engineering designs and demonstration of industry-scale technologies and shared infrastructure for cost-effective decarbonisation within industrial clusters.
2. develop credible and investible plans for regional industrial cluster decarbonisation by 2023 for operation by 2040.
3. advance and accelerate knowledge sharing through multidisciplinary research in cross-cutting themes to drive progress towards net zero.

To meet these objectives, the IDC centred around three core workstreams[6,7]:

1. **IDC Deployment Projects:** £172 million in funding from IDC was matched by £261 million from the private sector to deliver detailed and cost-effective decarbonisation designs to advance nine first-of-a-kind IDC Deployment Projects. This report is an outcome of this workstream.
2. **Cluster Plans:** £8 million was awarded by the IDC to develop blueprints for achieving net zero emissions in six selected industrial clusters. Published in October 2023, *Enabling net zero: a plan for UK industrial cluster decarbonisation* encapsulated learnings from the cluster plans and set out a national vision and recommendations for making the plans a reality.
3. **Industrial Decarbonisation Research and Innovation Centre (IDRIC):** Funded through a £20 million investment from IDC, IDRIC served as a multidisciplinary research and innovation centre focused on building a UK knowledge base on whole-system solutions for decarbonising industry.

Over the past five years, these three workstreams delivered significant progress toward realising four low carbon clusters by 2030.

Figure 1: Mapping of the nine IDC Deployment Projects to the UK's major industrial regions[8]

ABOUT THIS REPORT

Enabling net zero: progress on deploying CCS to decarbonise UK industrial clusters provides an overview of the nine IDC Deployment Projects and their contribution towards UK CCS and low carbon hydrogen goals. It also details their potential wider economic and social benefits. The Report highlights the challenges faced and identifies the lessons learnt by the IDC Deployment Projects. The Report provides practical insights and actionable next steps for project developers, government stakeholders, and investors who seek to follow in the footsteps of the IDC Deployment Projects. Lastly, it concludes by recommending actions needed to address outstanding roadblocks for these first-of-a-kind projects and the continued support required for the wide scale rollout of CCS and low carbon hydrogen.

The Report comprises six sections:

1

Section 1: The importance of CCS to achieving net zero emissions

The first section outlines the UK's commitment to climate change and the importance of developing a CCS sector for reducing industrial emissions, including by enabling low carbon hydrogen production. It also highlights the specific CCS and low carbon hydrogen goals the UK has set forth, and recent policies and legislation passed in support of those goals.

2

Section 2: The UK's leadership in CCS

The second section explores the UK's competitive advantages for deploying CCS, the intentional steps it is taking to establish a CCS market, and the IDC's key role in jumpstarting industrial cluster decarbonisation through funding the nine IDC Deployment Projects.

3

Section 3: Overview of the IDC Deployment Projects

The third section presents an overview of the nine IDC Deployment Projects. It also highlights the significant milestones that each project has achieved to date.

4

Section 4: The IDC Deployment Projects' contributions towards UK goals

The fourth section presents an overview on the contributions the nine IDC Deployment Projects collectively can have towards national CCS and low carbon hydrogen goals. It also highlights the economic and social benefits the projects expect to realise.

5

Section 5: The challenges faced by and learnings from the IDC Deployment Projects

The fifth section presents the key challenges faced thus far by the nine IDC Deployment Projects, including strategies applied to overcome these and the lessons learnt. Specific consideration is given to technical, regulatory, procurement, permitting, and execution factors.

6

Section 6: Steps required to enable widespread CCS and low carbon hydrogen deployment in the UK

The sixth and concluding section of the Report presents recommendations to maintain the momentum, initiated by the IDC, towards industrial decarbonisation. These recommendations are needed to enable the wide scale rollout of CCS and low carbon hydrogen projects across the UK.

Section 1: The importance of CCS to achieving net zero emissions

The UK is committed to addressing climate change

The UK has demonstrated consistent international climate leadership for decades. The landmark Climate Change Act 2008 established the world's first legally binding framework to reduce the UK's GHG emissions. It initially committed the UK to an 80% emissions reduction target by 2050 compared to 1990 levels. This was amended to 100% in 2019, binding the UK to achieve net zero emissions by 2050: a world first for any major economy. The Climate Change Act also introduced legally binding carbon budgets, which cap emissions over successive five-year periods enroute to net zero[9]. This sets a clear direction for the Government and helps benchmark progress towards the UK's overarching targets.

The UK was the first major economy to halve its emissions by 50% compared to 1990 levels, achieving this in 2022[2]. A key contribution to the UK's efforts was a 73% drop in power sector emissions between 1990 and 2022[10]. As the rollout of low carbon power sources accelerates, gains in power sector decarbonisation will start to level off. Continued progress towards net zero will therefore depend on reducing emissions from other sectors of the UK's economy, including industry.

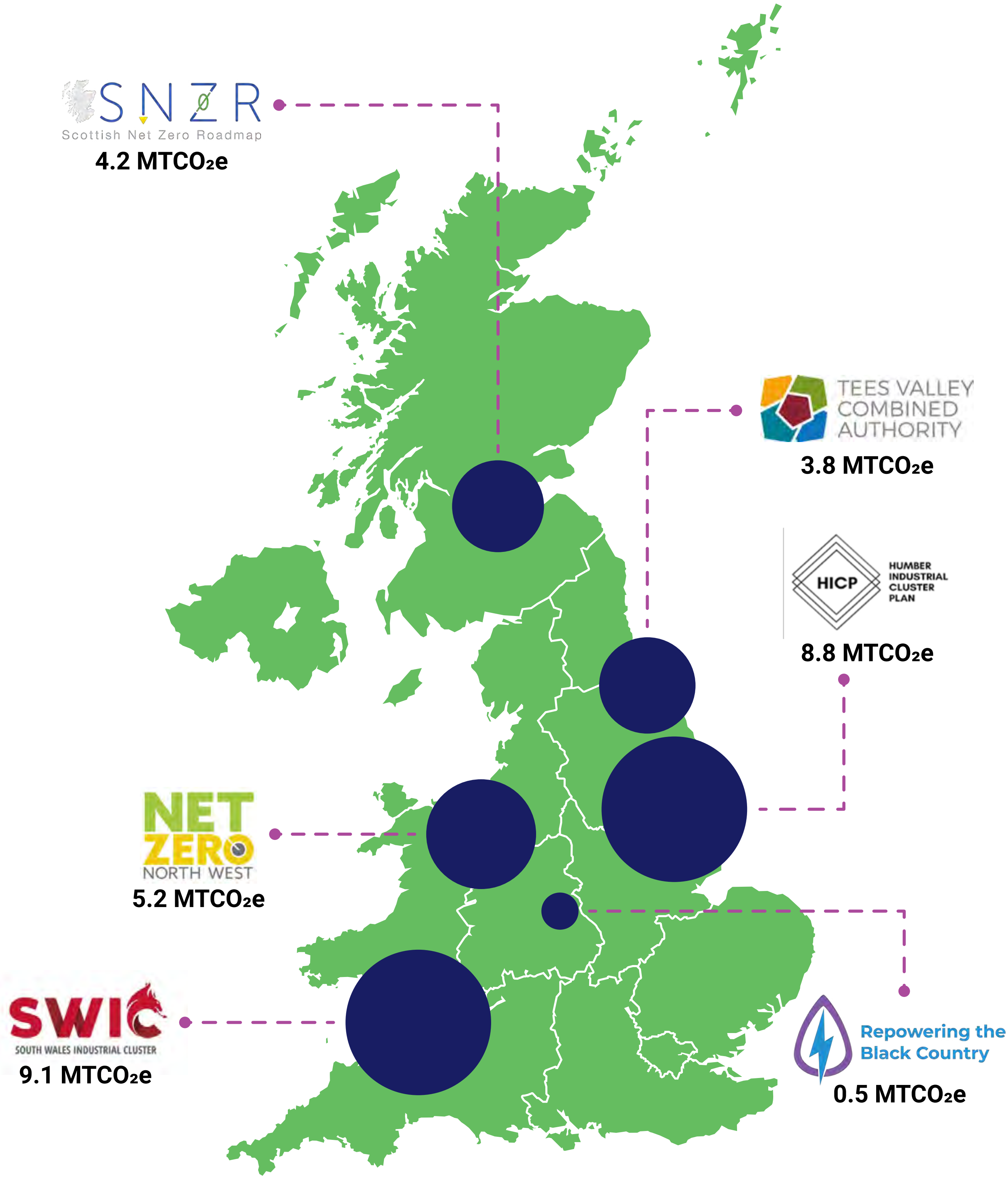
Decarbonising industrial clusters is crucial to achieving net zero

Industrial emissions were 14% of the UK's total emissions in 2022[3]. Around half of these emissions came from six regions with high concentrations of industrial sites, otherwise known as industrial clusters **(Figure 2)**[11].

Electrification is a valid decarbonisation pathway for some industrial sites. However, it is not always feasible for energy-intensive industrial sectors like chemicals, glass, paper and pulp, oil refining, iron and steel, cement, and ceramics. The CCC therefore considers the deployment of CCS technologies as a "necessity not an option"[1] to decarbonise some industrial sites. CCS captures CO_2 emissions produced from industrial operations or processes and transports them to permanent geological storage sites[1].

CCS is also a key enabler for producing low carbon (blue) hydrogen at scale, which can further unlock or accelerate decarbonisation as

Figure 2: Map of large point sources of GHG emissions addressable by each IDC industrial cluster (NAEI 2019)[8]



hydrogen has multi-sector applications in the future energy system. These include industrial fuel switching, flexible power generation, long-distance and heavy-duty transport, and long duration energy storage.

Deployment of CCS and low carbon hydrogen infrastructure in these industrial clusters represents an ideal starting point for the emerging carbon capture industry[12]. Collective decarbonisation of clusters through shared infrastructure can lower the abatement cost while unlocking greater efficiency, collaboration, and innovation. This contrasts with each emitter taking a 'going it alone' approach[8].

The UK has actively supported the establishment and development of industrial clusters through various mechanisms such as the UKRI IDC. The Cluster Plan workstream developed detailed plans for six of the largest industrial clusters in terms of emissions, pictured in **Figure 2**. These plans, which are currently being implemented, outline an evidence-based approach to reaching net zero emissions by 2040, and centre around the IDC Deployment Projects[8].

Goals signal a roadmap towards net zero industry

To achieve the UK's net zero goals, the previous Government set out ambitious industrial decarbonisation, CCS, and low carbon hydrogen goals, in line with the recommendations of the CCC's sixth carbon budget[13]. The goals include:

By 2030

- deploy four low carbon (CCUS) clusters.
- capture 20 to 30 MTPA of emissions, including from the power and industry sectors.
- deploy 10 GW of low carbon hydrogen production capacity (half of which may be blue hydrogen enabled by CCS).

By 2040

- achieve the world's first net zero industrial cluster.

The above goals underscore the importance that CCS will play in the transition to net zero. In support of these goals, the Department for Energy Security and Net Zero (DESNZ) published in December 2023 its CCUS Vision[14], which outlines its approach to creating a self-sustaining UK CCUS market by 2035 **(Figure 3)**.

The CCUS Vision sets out a three-phase approach to move from first-of-a-kind projects to a competitive CCS market expected to boost the UK economy by £5 billion per year by 2050[14]. Phase 1 (2024 to 2030) aims to create a CCS market to store 20 to 30 MTPA of CO_2 by 2030. Phase 2 (2030 to 2035) aims to transition to a commercial and competitive market. Finally, Phase 3 (2035 onward) strives to have a self-sustaining CCS market that is not reliant on government support.

Figure 3: Three phased CCUS market approach from DESNZ's CCUS Vision[14]

PHASE 1

2024 to 2030

Market creation

Phase one is seeking to create a new commercial CCS market.

Government funding will stimulate the deployment of the first four CCS clusters across multiple industries (industrials, power plants, hydrogen).

Government is making significant progress in shaping the market via legislation, funding, commercial frameworks and cluster allocation.

PHASE 2

2030 to 2035

Transition to commercial market

Phase two will move from a government-led cluster sequencing approach to competitive allocation process.

The CO_2 transport network will be expanded to include Non-Pipeline Transport (NPT) options like road, rail, and shipping, opening the market for international imports of CO_2.

Reduced government support and diminishing need for government support packages.

PHASE 3

2035+

Self-sustaining market that achieves net zero in 2050

Phase three will have a self-sustaining market that incorporates different transport pathways to capture CO_2.

International companies will look to relocate to the UK to connect to the CCS system

Over time, the cost of capturing and storing CO_2 will reduce due to market conditions.

The new Government continues climate leadership

The July 2024 UK general election resulted in a change of government, who announced a series of new policies and legislation demonstrating a continued commitment to net zero. Specific policies and legislation include:

- **boosting energy independence and cutting bills through clean power by 2030,** achieved through legislation to unlock investment in energy infrastructure[15].
- **reforming the UK energy network with Great British Energy (GBE),** a publicly owned clean power company which will help accelerate the energy transition investment in "technologies such as nuclear, offshore wind, tidal, hydrogen and carbon capture[16]."
- **investing £7 billion into a National Wealth Fund (NWF)** to "decarbonise Britain's heavy industry…focused on five areas: green steel, green hydrogen, industrial decarbonisation, gigafactories, and ports[17]."
- **creating jobs in Britain's industrial heartlands,** including a just transition for the industries based in the North Sea[18].
- **leading international climate action on the global stage,** based on the UK's domestic achievements[18].

These announcements demonstrate the Government's continued commitment to the net zero agenda and illustrate the country's bold goal to develop globally leading clean energy sectors that strengthen the UK economy.

Section 2: The UK's leadership in CCS

Through the goals, policies, and vision statement outlined in **Section 1**, the UK is laying the foundation for developing a sustainable, mature CCS market. This will unlock a low carbon blue hydrogen market and help achieve the UK's 2050 net zero goal. The UK is well placed to lead CCS globally due to its competitive advantages in its geology, existing infrastructure, and sector expertise. It is capitalising on these to incubate a supportive market environment for developing CCS projects and to attract private sector investment to deliver them.

The UK's geology and sector expertise provide distinctive advantages

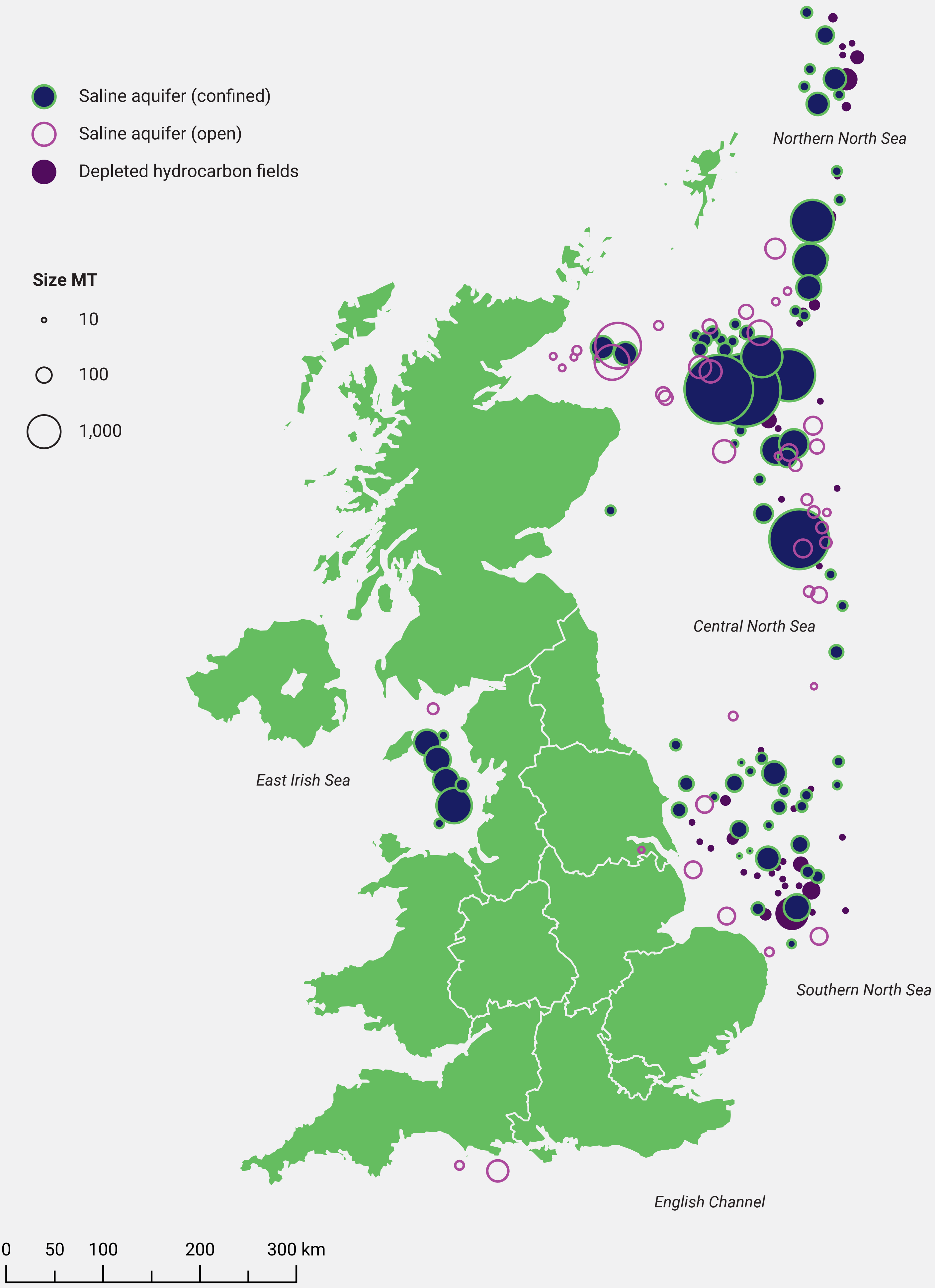
The UK has an estimated 78 billion tonnes of theoretical CO_2 storage capacity, accounting for approximately 25% of Europe's CO_2 storage potential **(Figure 4)**[19]. This is primarily located across 500 depleted oil and gas fields or saline aquifer sites in the Northern, Central, and Southern North Sea[14]. By harnessing the potential of the UK Continental Shelf, the UK can not only decarbonise domestic industrial emissions but also offer storage capacity to other countries, thereby realising additional emissions reduction and economic opportunities through CCS.

The UK's existing energy infrastructure offers another advantage, with the UK being the second largest natural gas and crude oil producer in Europe[20]. Rather than building entirely new pipelines to transport CO_2, some projects have the potential to repurpose existing or currently unused infrastructure. This approach can minimise capital costs and reduce timelines in bringing CCS projects online.

In addition, the UK can apply its expertise in the oil, gas, and petrochemical sectors to the nascent CCS sector. While not identical, similarities exist across the design, construction, and operational phases of the asset lifecycle. Many UK-based companies involved in oil and gas are also developing low carbon solutions adjacent to CCS, including low carbon power and low carbon hydrogen. The UK can leverage this knowledge to ensure CCS development is sustained and built upon across multiple sectors, from power to industry.

When it comes to knowledge and innovation, the UK is fortunate to have world leading universities and research institutes that focus on CCS technologies. These include the University of Edinburgh (Carbon Capture Group, member of Scottish Carbon Capture and Storage)[21], Imperial College London (Carbon Storage Research Centre)[22], and the University of Sheffield's Energy 2050 Centre[23,24]. These institutions have conducted leading research in carbon capture methods, transport, and storage solutions over an extended period of time. The UK also serves as the headquarters to organisations such as the Institution of Chemical Engineers and the Carbon Capture and Storage Association (CCSA), which provide platforms for industry collaboration, knowledge sharing in the engineering sector while also upskilling and training the future workforce in CCS technologies.

Figure 4: Distribution of storage capacity in the UK Continental Shelf[14]



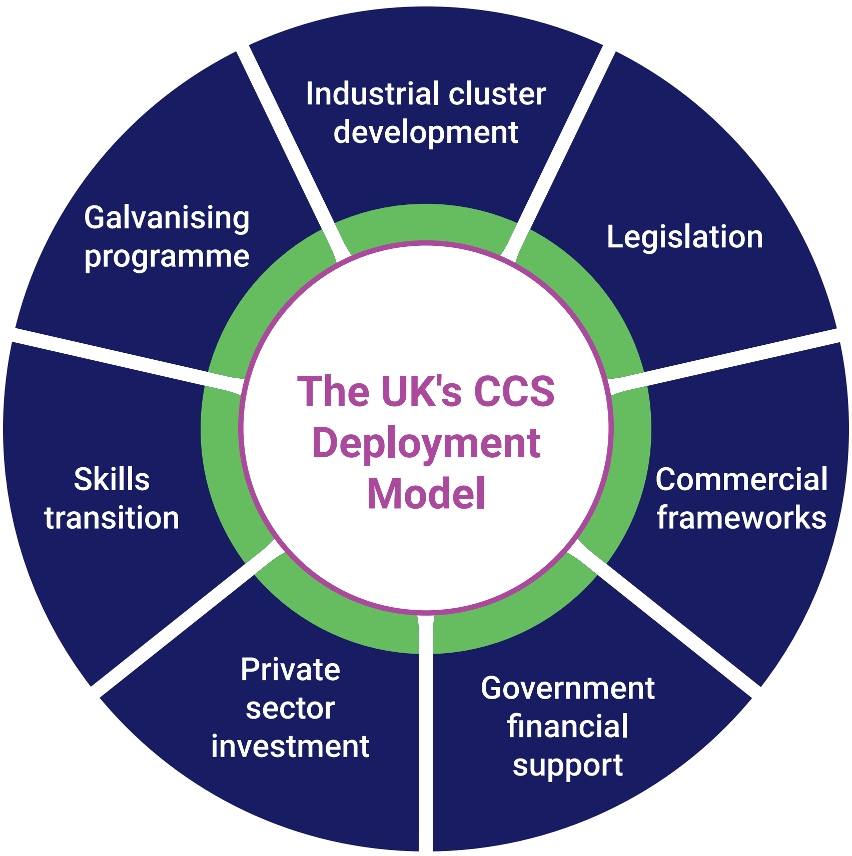
The UK is taking intentional steps to stimulate CCS sector growth

These advantages give the UK a unique opportunity to position itself as a world leader in developing the CCS sector. To deliver their cluster-based decarbonisation approach, successive governments have pulled several levers designed to encourage the development of CCS projects **(Figure 5)**.

The UK's model to deliver the CCUS Vision and deploy the first wave of IDC Deployment Projects includes:

- **sequencing development of industrial clusters:** Applying a logical progression for how CCS and low carbon hydrogen projects will be deployed through the cluster sequencing process.
- **passing sector specific legislation:** Developing robust regulatory frameworks for the new sectors.
- **developing commercial frameworks:** Creating the financial mechanisms through business models to de-risk projects.
- **providing initial financial support:** Directly supporting capital and operational expenditures (CAPEX and OPEX) required for CCS projects.
- **incentivising private sector investment:** Utilising public capital and revenue funding arrangements to stimulate the private sector to invest in new industries of the future.
- **supporting the skills transition:** Building a workforce for the green economy.
- **establishing a programme to galvanise action:** Launching a concerted effort to kick-start first-of-a-kind projects.

Figure 5: The UK's CCS deployment model supporting a cluster-based approach to industrial decarbonisation



Sequencing development of industrial clusters

The cluster sequencing process is how the Government is identifying and supporting a logical sequence in deploying low carbon clusters and projects in the UK[25]. It launched in 2021 and is being implemented through a two-phase approach. The first two low carbon clusters to be deployed were selected in October 2021 and the emitter carbon capture projects for both clusters were selected in March 2023[26]. After this, negotiations began between the selected parties and DESNZ for project financial support.

DESNZ selected two additional clusters for deployment in July 2023 and announced a process for the expansion of one of the initial clusters in December 2023, also expressing their commitment to the future expansion of the second initial cluster. Selection of emitter projects for the two additional clusters is expected in the near term. The cluster sequencing process has sent a strong signal of the Government's commitment to realise CCS and low carbon hydrogen projects and has fuelled the growth of the UK project pipeline.

Passing sector specific legislation

The Energy Act became law in 2023. It is designed to help deliver the transformation required in the UK energy landscape to achieve net zero. This includes legislation supporting the new CCS and low carbon hydrogen industries, as well as facilitating key technological shifts in power generation[27].

The Act includes provisions for the development and implementation of CCS and low carbon hydrogen business models[28], offers safeguards to investors against specific high impact and low probability risks, and appoints Ofgem as the economic regulator of CO_2 Transport and Storage (T&S)[29]. This allows Ofgem to award, amend, transfer, and terminate CO_2 T&S licences.

Developing commercial frameworks

Due to the nascency of the UK's CCS and low carbon hydrogen sectors, such projects are dependent on financial support. This support is provided through business models provisioned by the Energy Act, following the selection of the cluster or emitter project in the cluster sequencing process. The Government has been developing the CCS and low carbon hydrogen business models since 2019. These have evolved over time through industry working groups and public consultation processes. Five bespoke business models have been developed, with an additional four planned[iii]. Once finalised, these nine business models will represent a significant milestone as they will cover the full spectrum of the CCS and low carbon hydrogen value chains.

The business models are essential commercial frameworks to de-risk CCS projects for potential investors and developers. They provide financial support to ensure first-of-a-kind projects are economically viable (earn a fair and reasonable return) and offer long-term revenue certainty (such as through a regulated asset base or contracts for difference mechanisms). Furthermore, the business models have been designed to ensure a mutually acceptable position when considering the distribution of risk across the CCS value chain and between the Government and private sectors. This was a key recommendation from a National Audit Office report, which found previous UK attempts to develop the CCS market failed in part due to inadequate financial support[30].

Providing initial financial support

The UK has announced several capital and revenue funding measures to support the financial requirements of the business models. This includes the £1 billion CCS Infrastructure Fund (CIF), announced in March 2021 to support CAPEX for strategic infrastructure. This capital budget will support transport and storage networks and Industrial Carbon Capture (ICC) projects[31]. In addition, the 2023 Spring Budget committed up to £20 billion over the next two decades for the early deployment of CCS[32]. Direct funding from government will subsidise the CAPEX and OPEX required for first-of-a-kind projects.

Incentivising private sector investment

The Government is also looking to turbocharge private sector investment towards clean energy and decarbonisation, with two measures announced as of July 2024. These are the £7.3 billion NWF and the establishment of GBE. The NWF is designed to support commercial entities to invest in sustainability initiatives, with the aim of generating £3 of private investment for every £1 government invests[33]. Through this, it expects £20 billion in private sector investment to be brought in. Likewise, GBE, backed by £8.3 billion in capital, will deploy this funding towards achieving Britain's pathway to energy independence[34]. This includes delivering CCS projects which involve new CCS facilities, retrofitting of existing power plants with CCS technology or building the appropriate infrastructure to transport CO_2[34]. These funding announcements signify the Government's continued commitment to kickstart the CCS sector and provide confidence to the private sector to realise their projects.

iii Business models developed: Industrial Carbon Capture (ICC), Waste ICC, Dispatchable Power Agreement (DPA), Transport and Storage Regulatory Investment (TRI) Model, and Hydrogen Production Business Model (HPBM). Business models under development: Hydrogen Transport (HT), Hydrogen Storage (HS), Power Bioenergy CCS (BECCS), Greenhouse Gas Removals (GGRs). The Government is also consulting on Non-Pipeline Transport (NPT), which could either be its own business model or integrated into existing business models

Supporting the skills transition

The UK already has a strong energy sector that "could transition to service a growing CCS industry, allowing the retention and creation of high value jobs[35]". The creation of a CCS sector in the UK is expected to create roughly 50,000 jobs by 2030[14] in low carbon energy, supporting a clean growth revolution while supporting high quality, high paying jobs in the cluster regions.

To achieve the workforce of the future that is qualified and capable of working in the CCS industry, the UK is harnessing its rich knowledge base of industrial and technical expertise to advance skills and innovation in the green economy. For example, the Green Jobs Delivery Group is accelerating the supply of skilled workers for low carbon sectors, and the North Sea Transition Deal has developed a People and Skills Plan to ensure the UK's highly skilled oil and gas workforce can successfully transition into the CCS industry. Furthermore, a £120 million package has been allocated to the Institutes of Technology to deliver higher technical education and mature green skills. Also, the Free Courses for Jobs initiative will offer Level 3 (A-level equivalent) qualifications to adults to transition them to roles in the green economy[35].

This combined package of training and qualifications for those seeking employment in the CCS sector complements the additional steps being taken to bolster the CCS market. Ensuring the UK has the right skills mix to mature and expand the CCS market in the UK will lead to future opportunities that will place the 'UK at the forefront of global CCUS markets'[31].

Establishing a programme to galvanise action

The IDC was established as a centralised programme to support the decarbonisation of six of the largest UK industrial clusters. The concentration of the Government's endeavours to demonstrate industry-scale technology through the IDC has successfully:

- **unlocked project development:** The £172 million provided by the IDC supported the necessary DEVEX to kickstart development of these nine first-of-a-kind IDC Deployment Projects, paving the way for broader adoption and scale-up of CCS and low carbon hydrogen. The funding helped develop several projects to a sufficient level of detail for them to be selected for DESNZ's cluster sequencing process. This is a major milestone that signals the Government's commitment, sets a path for projects to take FID, and enabled significant progress towards delivering Phase 1 of the UK's CCUS Vision.

- **increased collaboration:** The IDC fostered collaboration among stakeholders through the IDC Deployment Projects. The IDC Deployment Projects which comprised many subprojects promoted the sharing of knowledge and lessons learnt across the value chain, enhancing efficiency and effectiveness.
- **de-risked private sector involvement:** The IDC initiative reduced perceived and actual risks for private stakeholders. This assurance encouraged management buy-in for CCS and low carbon hydrogen projects and increased appetite to invest in these projects. By progressing the projects, the IDC funding is expected to facilitate the deployment of billions of pounds in private investment that will create new jobs and provide opportunities for UK companies along the supply chain.

The concerted effort led by the IDC has set in motion the UK's CCS deployment model and is building momentum toward widespread industrial cluster decarbonisation.

The UK has intentionally structured the key components necessary to mature the CCS sector, starting with the IDC Deployment Projects. The following sections explore the nine first-of-a-kind projects in more detail, including their potential contribution to the UK's industrial decarbonisation and net zero goals, challenges faced, and lessons learnt.

> IDC funding unlocked this development. We would not have been put on this path without it.
>
> *Adam Young, Humber Zero*

> IDC was fundamental for moving the projects forward. It allowed us to develop compelling stories to get Track-1 reserve and shortlist for Track-2.
>
> *Charlie Youngs, SNZI*

> IDC funding was a vote of confidence in the project, so partners could go to their boards and say the UK government supports the project.
>
> *David Parkin, HyNet*

Section 3: Overview of the IDC Deployment Projects

Introduction of the nine IDC Deployment Projects

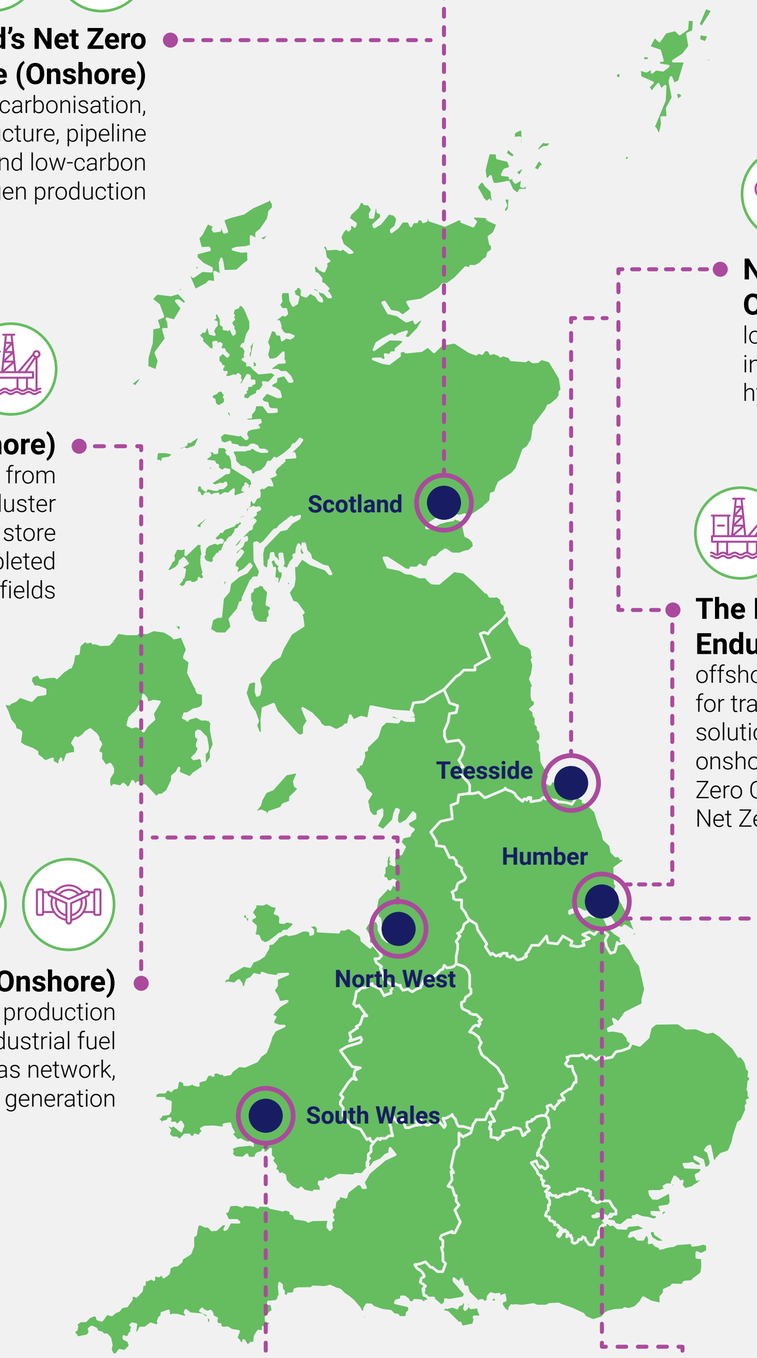
In 2021, the IDC announced the award of funding to nine projects through its IDC Deployment Projects workstream. These include three offshore projects and six onshore projects, three of which are closely associated with the respective offshore partners. These projects were selected to cover various elements of the CCS and low carbon hydrogen value chains based on the regional and national significance of their proposals, as well as their contributions to achieving net zero in their region by 2040, and their support for the UK's 2050 net zero goal.

All nine projects are based within designated industrial clusters in alignment with the UK's cluster approach to industrial decarbonisation. The IDC Deployment Projects are looking to build infrastructure across five of the UK's major industrial clusters: the North West, Teesside, Humber, Scotland and South Wales. The projects encompass CO_2 carbon capture, onshore and offshore CO_2 transport, CO_2 storage, low carbon hydrogen production, onshore hydrogen transport and storage, low carbon power stations, and hydrogen fuel switching. The nine IDC Deployment Projects that received the IDC funding are listed below and presented in **Figure 6**:

- HyNet Onshore
- HyNet Offshore
- Net Zero Teesside (NZT) Onshore
- The Northern Endurance Partnership (NEP)
- Zero Carbon Humber (ZCH) Partnership
- Humber Zero (HZ)
- Scotland's Net Zero Infrastructure (SNZI) Onshore
- Scotland's Net Zero Infrastructure (SNZI) Offshore
- South Wales Industrial Cluster (SWIC)

The IDC Deployment Projects have progressed their technical design from the feasibility stage to more advanced phases, with intentions to take a positive FID in the short to medium term. By doing so, the projects will deliver detailed designs, prove their financial attractiveness, demonstrate techno-economic viability, raise external capital, and demonstrate the scale-up of low carbon technologies.

Figure 6: Overview of the nine IDC Deployment Projects



Scotland's Net Zero Infrastructure (Offshore)
offshore pipeline, subsea and well-related infrastructure to transport and inject CO_2 offshore for long-term secure storage

Scotland's Net Zero Infrastructure (Onshore)
onshore components of decarbonisation, including shipping infrastructure, pipeline transport and storage and low-carbon hydrogen production

Net Zero Teesside Onshore
low-carbon infrastructure including flexible gas power, hydrogen and CCUS

HyNet (Offshore)
transport CO_2 emissions from the North West industrial cluster and use CCUS methods to store safely offshore in depleted Liverpool Bay gas fields

The Northern Endurance Partnership
offshore CO_2 pipeline network for transport and storage solutions for two first-of-a-kind onshore capture projects, Zero Carbon Humber and Net Zero Teesside

HyNet (Onshore)
low-carbon hydrogen production facilities used for industrial fuel switching with local gas network, transport and flexible power generation

Zero Carbon Humber Partnership
creating parallel CO_2 and H_2 pipelines linking the region's industrial emitters for emissions capture and transport, as well as fuel-switching to hydrogen for sustainable, low-carbon energy

South Wales Industrial Cluster
regional hydrogen production, CO_2 transportation, and new low-carbon collaboration between industry, agriculture, towns/cities and transport

Humber Zero
carbon capture infrastructure providing cost effective decarbonised energy supply to industry and lower carbon products

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Deployment Project technologies key

- Industrial carbon capture technology
- Offshore pipelines and subsea CO_2 storage
- CO_2 and H_2 transportation pipelines
- Low-carbon power stations
- Industrial infrastructure

Overview of the IDC Deployment Projects

Collectively, the nine IDC Deployment Projects will enable wide scale rollout of CCS and low carbon hydrogen across the UK by delivering large-scale first-of-a-kind projects. The table below provides a high-level overview of the nine IDC Deployment Projects and their unique attributes. The information presented in **Table 1** refers to the IDC-funded project scope only. In addition to the IDC Deployment Projects, there is additional scope (funded through other sources) or planned expansion phases within the industrial clusters. These will utilise the shared infrastructure being developed by IDC Deployment Projects and increase the scale of their decarbonisation impacts. This is highlighted in each of the project profiles below and quantified in **Section 4** and **Appendix 2** of this report.

Table 1: Overview of the nine IDC Deployment Projects

Project Name	HyNet Onshore	HyNet Offshore	Net Zero Teesside Onshore	The Northern Endurance Partnership	Humber Zero
Commercial operations target date[iv]	2028	2028	2028	2028	2029
IDC-funded CO_2 capture capacity	1.7 MTPA	-	2.0 MTPA	-	3.8 MTPA
IDC-funded initial CO_2 transport and storage capacity[v]	4.5 MTPA	4.5 MTPA	4.0 MTPA	4.0 MTPA	-
IDC-funded H_2 production capacity	-	-	-	-	-
Cluster region	North West	North West	Teesside	Teesside and Humber	Humber
Cluster sequencing track	Track-1	Track-1	Track-1	Track-1	Track-2
Business model[viii]	TRI, ICC, HT, HS	TRI	TRI, DPA	TRI	DPA, ICC
Main IDC funded project partners	Cadent, Eni, Essar Oil, Heidelberg Materials, Inovyn, Progressive Energy	Eni, Progressive Energy	bp, Equinor	bp, Equinor, Total Energies	Phillips 66, VPI
IDC grant funding awarded[6]	£19.5 million	£13.3 million	£28.1 million	£24.0 million	£12.7 million
Pledged match funding[6]	£25.7 million	£13.3 million	£35.7 million	£24.7 million	£12.7 million

[iv] The commercial operations target date refers to the start of operation following the completion of the commissioning activity.

[v] Refers to the CO_2 transport and storage capacity for the initial phase of the project. Specifically, HyNet Onshore/HyNet Offshore refers to the Track-1 and Track-1 expansion capacity and NZT Onshore/NEP refers to the Track-1 capacity.

[viii] Relevant business models are ICC: Industrial Carbon Capture, DPA: Dispatchable Power Agreement, TRI: CO_2 Transport & Storage Regulatory Investment, LCHP: Low Carbon Hydrogen Production, NPT: Non Pipeline Transportation, HT: Hydrogen Transport, HS: Hydrogen Storage. NPT, HT and HS to be developed. NPT could either be its own business model or integrated into existing business models.

Table 1: Overview of the nine IDC Deployment Projects

Project Name	Zero Carbon Humber Partnership	Scotland's Net Zero Infrastructure Onshore	Scotland's Net Zero Infrastructure Offshore	South Wales Industrial Cluster
Commercial operations target date[iv]	2030/2031	2030/2031	2030/2031	2031/2032
IDC-funded CO_2 capture capacity	1.4 MTPA	2.9 MTPA	-	2.5 MTPA
IDC-funded initial CO_2 transport and storage capacity[v]	-	5.0 MTPA	5.0 MTPA	2.5 MTPA[vi]
IDC-funded H_2 production capacity	600 MW	300 MW	-	470 MW
Cluster region	Humber	Scotland	Scotland	South Wales
Cluster sequencing track	Track-1 expansion	Track-2	Track-2	See footnote[vii]
Business model[viii]	TRI, LCHP, HT	TRI, LCHP, DPA	TRI, NPT	DPA, NPT, HT, LCHP
Main IDC funded project partners	Equinor, Mitsubishi, National Grid Ventures, Triton Power, University of Sheffield	National Gas Transmission, Shell, SSE Thermal, Storegga	Shell, Storegga	Dragon LNG, RWE, Shell, Wales & West Utilities
IDC grant funding awarded[6]	£21.5 million	£20.0 million	£11.3 million	£20.0 million
Pledged match funding[6]	£40.0 million	£19.6 million	£11.3 million	£18.4 million

[iv] The commercial operations target date refers to the start of operation following the completion of the commissioning activity.

[v] Refers to the CO_2 transport and storage capacity for the initial phase of the project. Specifically, HyNet Onshore/HyNet Offshore refers to the Track-1 and Track-1 expansion capacity and NZT Onshore/NEP refers to the Track-1 capacity.

[vi] The captured CO_2 emissions will be exported to a liquefication and shipping facility for transport to a permanent CO_2 store.

[vii] The SWIC cluster has not yet been formally selected by the Government.

[viii] Relevant business models are ICC: Industrial Carbon Capture, DPA: Dispatchable Power Agreement, TRI: CO_2 Transport & Storage Regulatory Investment, LCHP: Low Carbon Hydrogen Production, NPT: Non Pipeline Transportation, HT: Hydrogen Transport, HS: Hydrogen Storage. NPT, HT and HS to be developed. NPT could either be its own business model or integrated into existing business models.

HyNet (Onshore)
low-carbon hydrogen production facilities used for industrial fuel switching with local gas network, transport and flexible power generation

Deployment Project technologies key

Industrial carbon capture technology

CO_2 and H_2 transportation pipelines

HyNet Onshore

Overview of IDC-funded scope:

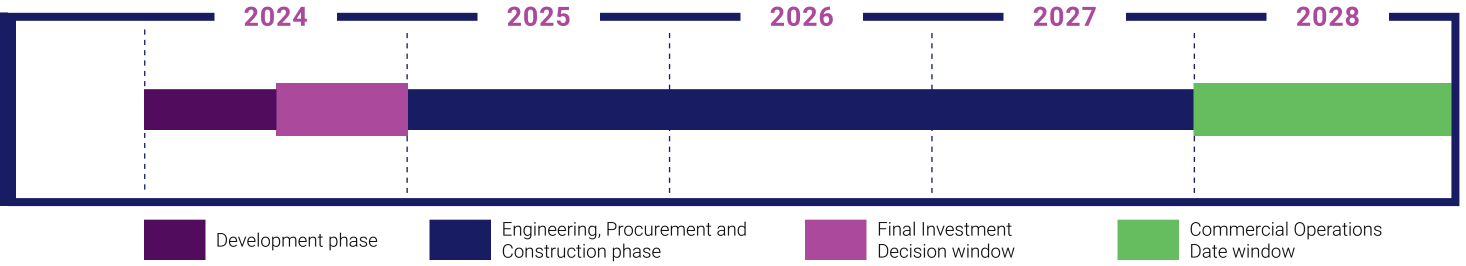
The IDC scope of HyNet Onshore comprises major components of the CCS and hydrogen value chains, including industrial CO_2 capture and transport, as well as hydrogen distribution and storage. This project is led by Progressive Energy, and the project partners include Cadent, Eni, Essar Energy Transition (EET), Heidelberg Materials, and Inovyn.

The project is centered on the industrial complex near Ellesmere Port, serving several of the UK's most significant industrial emitters and providing shared infrastructure to enable carbon capture and industrial fuel-switching in North West England and North Wales[6]. The HyNet Onshore IDC-funded scope is anchored by carbon capture facilities at Heidelberg Materials' Padeswood Cement Plant, to be deployed in Track-1, and EET Fuel's Fluidised Catalytic Cracker at Stanlow Manufacturing Complex refinery. Together they will capture up to 1.7 MTPA of CO_2[36,37] and connect to the onshore CO_2 transport network (new build pipeline as part of HyNet Onshore and repurposed pipelines as part of HyNet Offshore). The overall CO_2 network is sized for 4.5 MTPA and will in future accommodate, where necessary by expanded scope, CO_2 flows from the wider HyNet industrial cluster, including EET Hydrogen's Production Plant 1, Viridor's Runcorn Energy from Waste facility and Encyclis's Protos Energy Recovery Facility.

Figure 7: HyNet Onshore indicative project timeline[ix]

Project Timeline[40]:

Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process



The hydrogen produced at Stanlow will be transported by a 125 km onshore hydrogen pipeline with a capacity of 4.25 to 6.75 GW, dependent on the operating pressure[37]. Cadent's dedicated network will transport hydrogen from production to demand points and Inovyn's storage assets in the Cheshire salt fields, to enable supply and demand balancing[6]. This pipeline will be one of the UK's first hydrogen pipeline networks[38].

Impact:

The HyNet Onshore project, together with its offshore scope, will enable the decarbonisation of the North West. The capacity of the CO_2 and H_2 pipelines have been designed with future demand beyond the initial IDC Deployment Projects scope in mind. For example, additional flows from EET's low carbon hydrogen production projects in future phases, which could enable 30 TWh capacity by 2030[6,39]. The extensive regional hydrogen network that Cadent is developing will be used across multiple sectors, including industrial fuel switching, blending into the local gas network, hydrogen transport and flexible power generation[6].

Significant milestones and progress:

HyNet Onshore has achieved the following:

- **laid the foundation for regional decarbonisation:** HyNet demonstrates the strong potential impact of shared infrastructure to enable wider scale decarbonisation. To date, over 40 organisations have registered to decarbonise through HyNet[41], highlighting the potential benefits of a cluster wide approach and impacts to come.
- **secured key consents:** HyNet received DCO approval from the Secretary of State for the onshore CO_2 pipeline in March 2024[42], which allows for the construction, operation, and maintenance of the infrastructure[6].
- **progressed towards FID:** The onshore CO_2 pipeline also developed signed Heads of Terms with DESNZ as a world-first example of agreement being reached on a regulated asset base business model. The successful completion of these steps is a major milestone for the project, which positions HyNet to take FID in Autumn 2024[42].

ix HyNet CO_2 FID and COD are shown. HyNet H_2 FID & COD is expected later as the project scope is separated between CO_2 and H_2.

HyNet (Offshore)
transport CO_2 emissions from the North West industrial cluster and use CCUS methods to store safely offshore in depleted Liverpool Bay gas fields

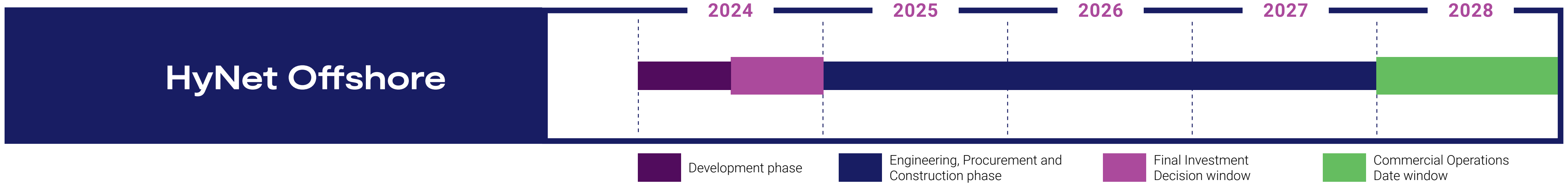
Deployment Project technologies key

Offshore pipelines and subsea CO_2 storage

Figure 8: HyNet Offshore indicative project timeline[x]

Project Timeline[40]**:**

Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.



Overview of IDC-funded scope:

The HyNet Offshore project will deliver the foundational infrastructure that will transport captured CO_2 emissions from the HyNet North West industrial cluster and safely contain these emissions offshore in the depleted gas fields of Liverpool Bay[6]. The project, led by Eni, comprises both onshore and offshore elements. The onshore components include the repurposing of an existing onshore pipeline and redevelopment of the Point of Ayr Gas Terminal (in North Wales), which connects to the new build CO_2 pipeline (part of the HyNet Onshore scope). The offshore components include repurposed offshore pipelines connecting to a new-build process platform and, from there to three repurposed well-head platforms, which together with the CO_2 injection wells, provide the required facilities for injection into the gas fields[41]. The infrastructure provides the North West cluster with an initial offshore transport and storage capacity of 4.5 MTPA of CO_2[43,44].

The repurposing of existing oil and gas infrastructure where viable has allowed the project to minimise new capital investment requirements, leading to cost-savings and environmental benefits[45]. The HyNet Offshore project also has lower compression requirements due to the use of depleted gas field storage, allowing CO_2 to be transported as a gas during the project's initial stage and as a liquid when transport capacity needs to be increased for future demand, and as reservoir pressure increases[43,45].

Impact:

HyNet Offshore complements HyNet Onshore by providing the connecting onshore and offshore transport and storage facilities needed for regional decarbonisation in the HyNet North West cluster. The project intends to expand capacity through a phased approach, from 4.5 MTPA (achieved by the Track-1 expansion process) to 10 MTPA in the future[43,44]. The delivery of this capacity will allow the transport and storage network to service more emitters in the region beyond the initial project scope. This will underpin the regional transition to a low carbon economy and move the region towards achieving net zero emissions by 2040.

Significant milestones and progress:

HyNet Offshore has achieved the following:

- **progress towards full regulatory approval:** Alongside the onshore scope of the project, HyNet Offshore has successfully completed FEED studies and expects to receive the necessary regulatory approval to reach FID by the Autumn of 2024[43,44].
- **engaged contractors for construction:** Project developers have taken a proactive approach to readying the project for construction by engaging contractors for offshore activities[6].

[x] HyNet CO_2 FID and COD are shown.

Net Zero Teesside Onshore
low-carbon infrastructure including flexible gas power, hydrogen and CCUS

Deployment Project technologies key

Industrial carbon capture technology

CO_2 and H_2 transportation pipelines

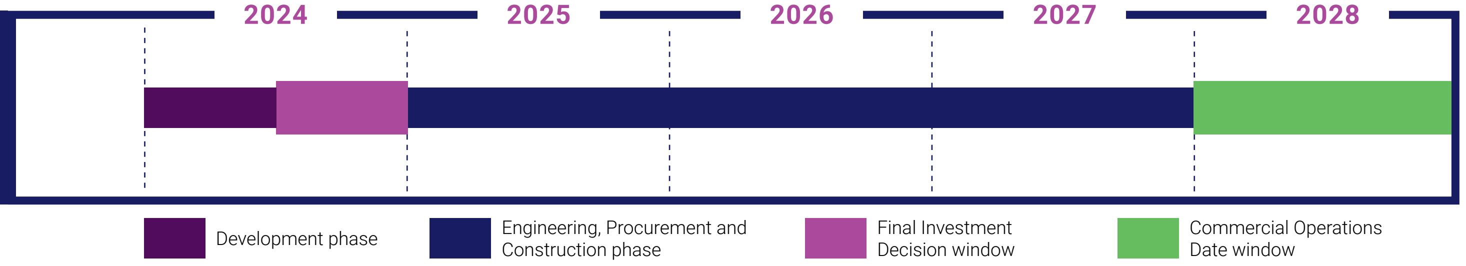
Low-carbon power stations

Net Zero Teesside Onshore

Figure 9: NZT Onshore indicative project timeline

Project Timeline[46]:

Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.



Overview of IDC-funded scope:

NZT Onshore is a low carbon infrastructure project located within the Teesside industrial cluster in North East England. The project is led by bp with support from its partner Equinor. It aims to deliver a combined cycle gas power station with amine-based carbon capture (NZT Power) to provide an expected 742 MW of flexible, dispatchable low carbon power in support of decarbonising the UK grid. The project will capture up to approximately 2 MTPA of CO_2 and be operational by 2028[46]. This project is one of the world's first commercial-scale power CCS projects[47].

The captured CO_2 will be collected via an onshore CO_2 pipeline, which will also serve the wider Teesside industrial emitters and is sized to accommodate flows of up to 10 MTPA. This system will further connect to the NEP system, allowing the CO_2 to be securely stored in subsea storage sites beneath the North Sea[48].

Impact:

The deployment of the power CCS project will represent the first major step in the decarbonisation of Teesside, acting as a key anchor tenant for the Teesworks site on the location of the former Redcar steelworks. The project will support a large supply chain, bringing jobs and investment to the area and supporting the development of Teesside as a low carbon hub.

The deployment of the onshore CO_2 transport system will support cross-sector industrial decarbonisation in the Teesside region, as the pipeline will include tie in points for current and future projects[49]. Those that will be enabled by infrastructure include current Track-1 projects such as BOC Teesside Hydrogen CO_2 Capture, bp H2Teesside and NZT Power, as well as potential future projects such as Kellas Midstream H2NorthEast, NorSea Carbon Capture and many others[50].

Significant milestones and progress:

NZT Onshore has achieved the following:

- **developed first-of-a-kind concept:** NZT Power would be one of the world's first gas fired power station with carbon capture to be developed at a commercial scale, providing low carbon dispatchable power[48].
- **concluding government negotiations:** NZT Power was the only power CCS project selected through the Track-1 cluster sequencing process by the Government[51]. The project is concluding business model support negotiations for a dispatchable power agreement[6].
- **progressed towards FID:** After accomplishing the milestone of receiving DCO approval in February 2024[52], the project is currently on track to take FID by the Autumn of 2024. The start of commercial operations is scheduled for 2028[46,47], making it one of the first IDC Deployment Projects to come online.

The Northern Endurance Partnership
offshore CO_2 pipeline network for transport and storage solutions for two first-of-a-kind onshore capture projects, Zero Carbon Humber and Net Zero Teesside

Deployment Project technologies key

Offshore pipelines and subsea CO_2 storage

The Northern Endurance Partnership

Overview of IDC-funded scope:

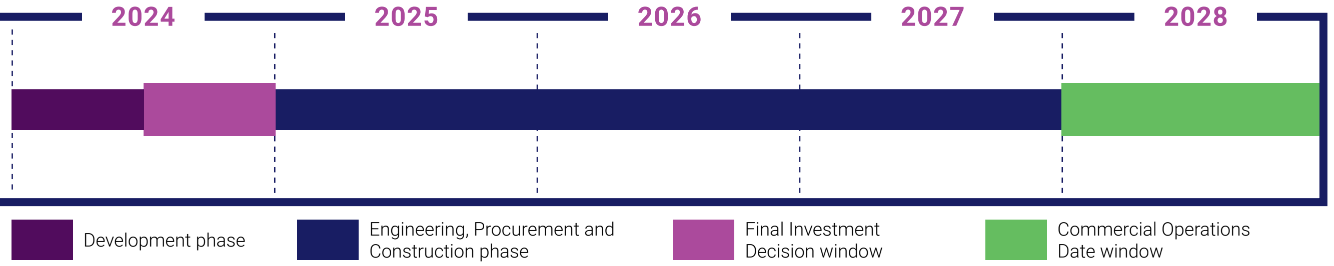
The NEP project aims to develop first-of-a-kind CO_2 transportation and storage infrastructure in the UK, connecting the Teesside and Humber Industrial Clusters to storage sites in the Southern North Sea, starting with the Endurance store. The project is led by bp, with support from project partners Equinor and Total Energies.

The offshore CO_2 transport network consists of a new 143 km pipeline from Teesside, sized for 10 MTPA capacity and a new 101 km pipeline from Humber, sized for 17 MTPA capacity[53]. Both these pipelines will be routed to the Endurance storage complex. The first phase of the project will transport and store around 4 MTPA of CO_2[6] from Teesside initially.

Figure 10: NEP indicative project timeline

Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.

Project Timeline[55]:



Impact:

The NEP's transport network provides connection for both the Teesside and Humber regions to the Endurance CO_2 storage complex. The first phase of the project will connect the Teesside region. In future phases, the Humber connection would be implemented and utilised by operators of bioenergy with CCS, low carbon hydrogen production and other industrial actors across the region[54]. The NEP is progressing the development of the Humber Carbon Capture Pipeline in advance of future phases, and the Humber connection would be implemented and utilized by operators of bioenergy with CCS, blue hydrogen production, power with carbon capture and other industrial carbon capture projects across the region. To support future demand, the project is undertaking an appraisal of further stores to enable ramp up of injection rates from 4 to 10 MTPA as the next phase with the potential to reach the full peak capacity of 27 MTPA, taking advantage of the many geological CO_2 stores in the Southern North Sea[53].

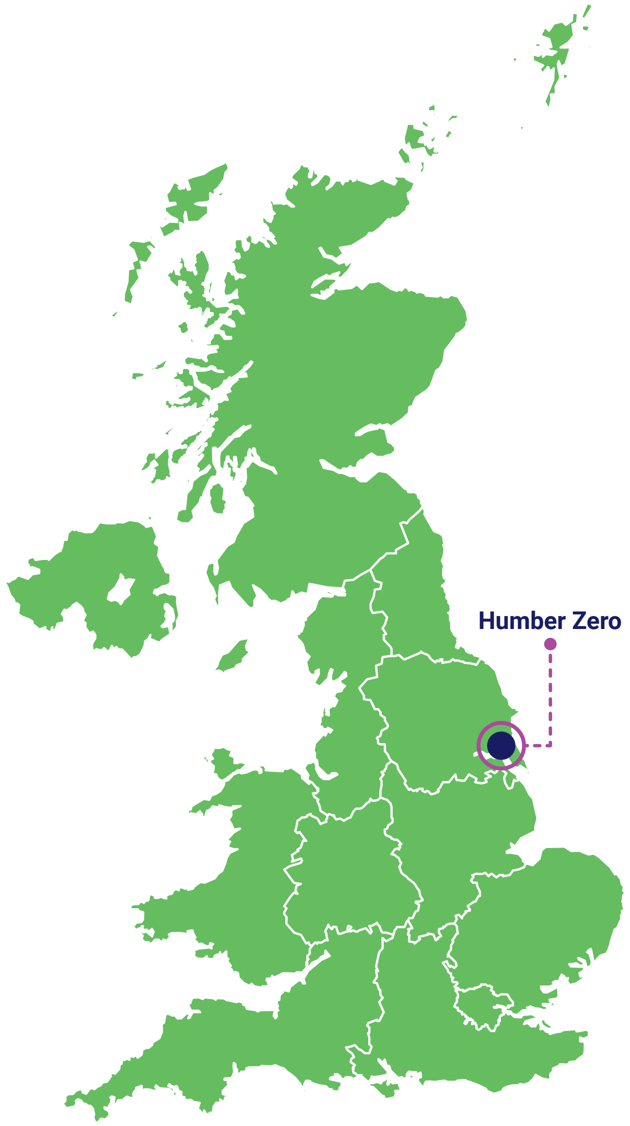
Significant milestones and progress:

NEP has achieved the following:

- **progressed towards FID:** NEP has substantially progressed the Transportation and Storage Regulatory Investment business model negotiations, leading to the agreement of Heads of Terms and paving the way for FID in Autumn 2024.
- **developed CO_2 entry specification:** NEP finalised the CO_2 entry specification requirements for third parties to connect to the NEP network. The project adopted a risk-based approach for setting the specification that is both robust (based on experimental results) and cost-effective[53], which will be made available when the Network Code is published.
- **concluded FEED to a high level of technical definition:** The evaluation of project readiness for entering the FEED phase and completion of FEED was conducted through several stage gated multi-discipline assurance reviews. This included cost and schedule reviews and an Independent Projects Analysis Pacesetter review. The results concluded the project is at a high degree of maturity and definition, thereby progressing to the next phase ready for construction[53].
- **selected Engineering, Procurement and Construction (EPC) contractors:** NEP has selected specialist contractors for engineering, procurement, and construction contracts across the offshore work packages. This includes the offshore pipeline system, offshore subsea injection system, power and communications cable, and offshore systems engineering[56]. The final contracts will be awarded following a positive FID, anticipated in Autumn 2024.

Humber Zero

carbon capture infrastructure providing cost effective decarbonised energy supply to industry and lower carbon products



Deployment Project technologies key

Industrial carbon capture technology

Low-carbon power stations

Overview of IDC-funded scope:

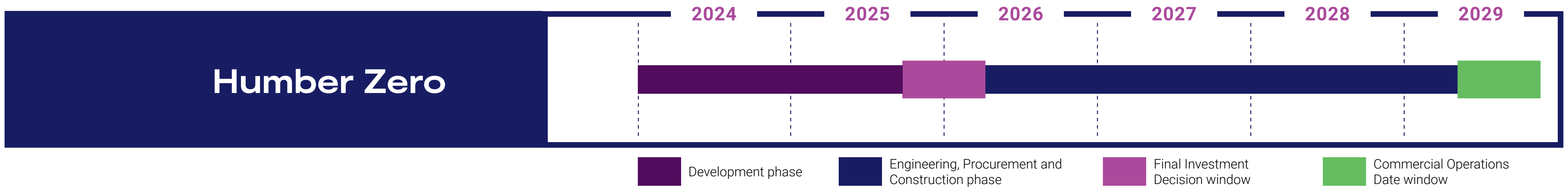
HZ is located on the northeast coast of England at Immingham and aims to deliver one of the world's largest carbon capture projects. The project could deliver up to 3.8 MTPA of abated CO_2 emissions via a post combustion carbon capture retrofit to two gas turbines (representing a total of 1052 MW) at VPI Immingham's combined Heat and Power (CHP) plant together with a post combustion carbon capture retrofit to the Fluid Catalytic Cracker (FCC) stack at the Phillips 66 Limited Humber's Refinery[6,57]. The CO_2 emissions from the HZ projects are intended to be transported and stored in the southern North Sea through the Viking CCS project[58].

Both VPI and Phillips 66 Limited provide crucial industrial operations to the region and the UK. The Phillips 66 Humber Refinery is the only European producer of speciality cokes, including battery-anode and graphite-electrode grades. Through this unique capability, the Humber Refinery is a world-scale supplier into the global electric vehicle battery and steel recycling industries, in addition to a significant production of sustainable aviation fuel and advanced biofuels. The VPI CHP plant is one of the largest facilities of its kind in Europe[59]. Since both sites are significant sources of emissions in the Immingham industrial complex, the project lays a strong foundation to capture 50% of emissions from the complex[59]. Both the VPI and Phillips 66 Limited's assets are classified as Critical National Infrastructure within the UK.

Figure 11: HZ indicative project timeline

Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

Project Timeline[60,61]:



Impact:

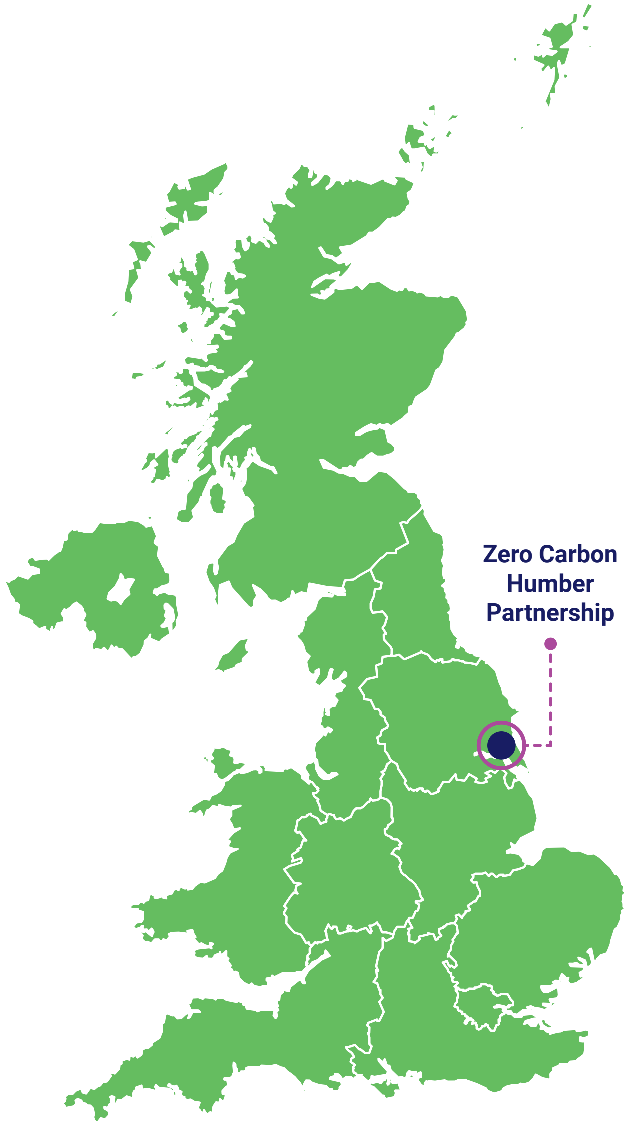
The CO_2 captured by the Humber Zero projects is intended to be routed to the Viking CCS system. CO_2 would be transported to Theddlethorpe via a newbuild pipeline before being directed via a repurposed offshore pipeline to the depleted Viking gas fields in the North Sea for permanent storage[58]. More broadly, Viking CCS plans to provide a decarbonisation pathway for the industries located in Humber, Lincolnshire, and Nottinghamshire regions[58]. Viking CCS is targeting 10 MTPA of CO_2 stored by 2030, rising to 15 MTPA by 2035[58].

Significant milestones and progress:

HZ achieved the following:

- **formed strong alignment with Viking CCS:** Humber Zero has an extensive working relationship with the Viking CCS project[62], where strong integration supports a mutual derisking. These two projects are working together to enable the CO_2 transport and storage infrastructure for the Humber region.
- **developed retrofit solution for CHP:** FEED completed for the VPI plant, which will be a first-of-a-kind, at-scale retrofit installation of carbon capture facilities to an existing CHP plant.
- **designed CO_2 capture facility integrated to an existing refinery:** The Phillips 66 Limited carbon capture project is a first-of-a-kind at scale project that involves retrofitting carbon capture facilities to an existing FCC stack[62]. The Phillips 66 Humber refinery will be one of the first in the world to deploy a CO_2 capture technology to an FCC to reduce its carbon dioxide emissions.
- **increased confidence in the design package:** FEED verification work was completed for the VPI project[60] to ensure that the FEED deliverables were at the appropriate maturity level and to provide greater confidence in the design package. The positive feedback confirms that VPI has a credible execution plan in place for the EPC phase and will be FID-ready in the near term.

Zero Carbon Humber Partnership
creating parallel CO_2 and H_2 pipelines linking the region's industrial emitters for emissions capture and transport, as well as fuel-switching to hydrogen for sustainable, low-carbon energy



Deployment Project technologies key

- Industrial carbon capture technology
- CO_2 and H_2 transportation pipelines
- Industrial infrastructure

Zero Carbon Humber Partnership

Overview of IDC-funded scope:

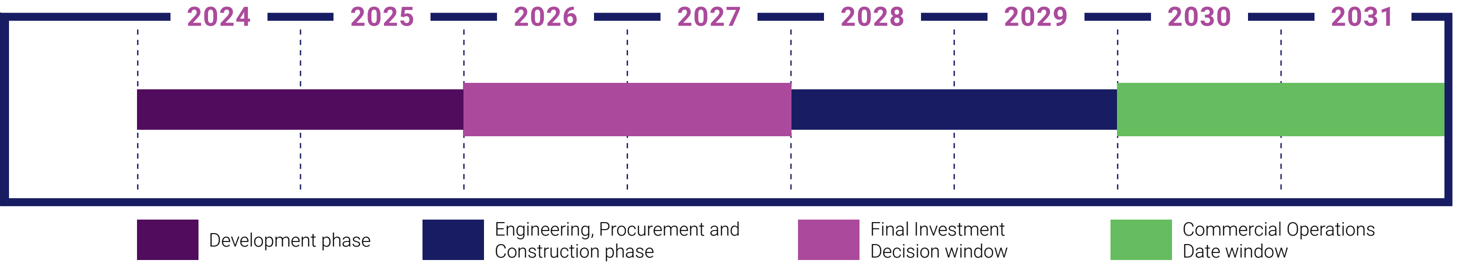
ZCH was established with the aim of delivering first-of-a-kind low carbon infrastructure. This includes onshore CO_2 and H_2 pipelines (sized for 17 MTPA and 10 GW capacity, respectively) linking the region's major emitters, enabling CO_2 emissions to be captured and transported, and fuel switching of end-users to hydrogen for a long-term sustainable transition to low carbon energy[6]. The onshore CO_2 pipeline is designed to link to the NEP project, providing CO_2 transport and storage for Humber and Teesside using CO_2 stores in the North Sea[6].

The project is led by Equinor, with the infrastructure to be designed and anchored around the Equinor H2H Saltend project. The H2H-Saltend project will develop a 600 MW hydrogen production facility, supporting fuel-switching at Saltend Chemicals Park, including the nearby Triton power station[63]. The ZCH shared infrastructure will enable at-scale decarbonisation of major industries, including chemicals, refineries, steel, manufacturing, bioenergy, and power stations in the region[54].

Figure 12: ZCH indicative project timeline

Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

Project Timeline[64]:



Impact:

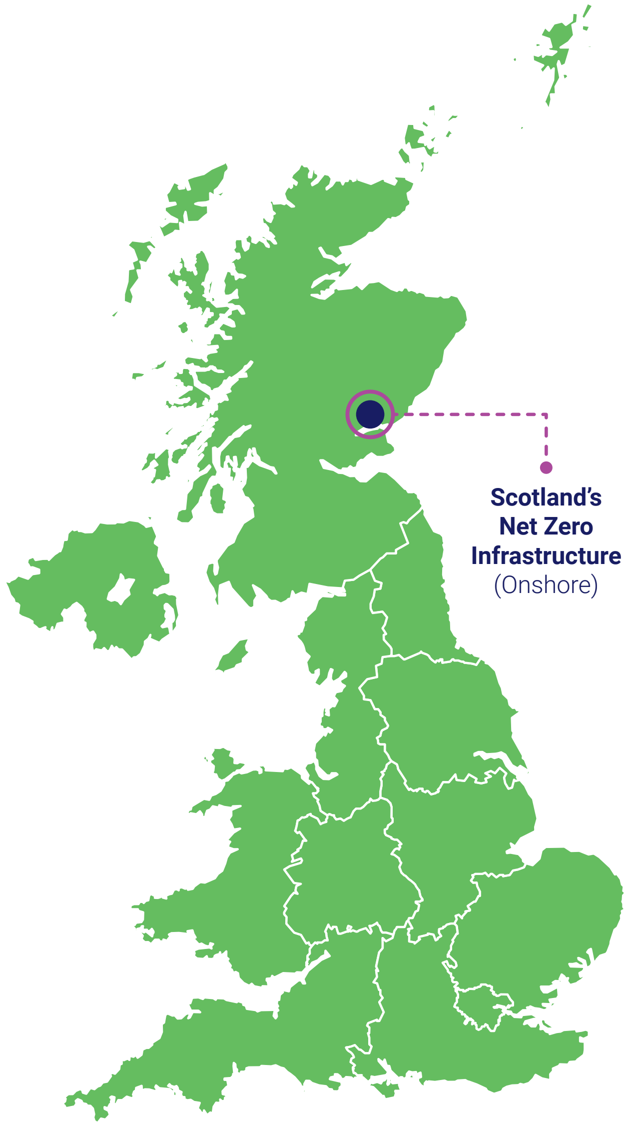
The development of the shared infrastructure (onshore CO_2 and H_2 pipelines) will enable wide scale decarbonisation of major industries in the Humber region. The CO_2 network will allow emitters such as Drax Power Station, SSE Keadby Power Station and British Steel to capture their emissions and transport them to the offshore CO_2 network[54]. The hydrogen network will connect major production sites such as the Uniper and Shell Humber H2ub, with potential offtakers such as SSE Keadby Hydrogen Power Station[54].

Significant milestones and progress:

ZCH has achieved the following:

- **advanced hydrogen project programme:** The Triton power station has successfully completed detailed design and engineering work to modify their existing gas-fired turbines to hydrogen powered turbines[65]. The project will modify the turbines to accommodate a 30% blend, with additional research being completed to explore adapting to 100% conversion fuel in the future[65]. The hydrogen required for fuel switching will be supplied by Equinor's H2H Saltend facility, which has recently received planning permission, progressed technical design significantly, and selected a long-term delivery partner[65].
- **completed supply chain qualification program:** Project researchers completed pilot supply chain qualification programs, Fit4Hydrogen and Fit4CCS, for a cohort of 38 supply chain companies[65]. This highlighted the potential job opportunities in the developing low carbon sector[65].

Scotland's Net Zero Infrastructure (Onshore)
onshore components of decarbonisation, including shipping infrastructure, pipeline transport and storage and low-carbon hydrogen production



Deployment Project technologies key

- Industrial infrastructure
- Industrial carbon capture technology
- Low-carbon power stations

Scotland's Net Zero Infrastructure (Onshore)

Overview of IDC-funded scope:

SNZI Onshore project was established to further design of the major onshore decarbonisation components of the Scottish industrial cluster. Storegga, via its subsidiary Pale Blue Dot Energy, led the project, working closely with the Acorn Development Agreement (ADA) partners Shell, Harbour Energy and North Sea Mid-stream Partners. The project also includes SSE, NECCUS, University of Strathclyde's Centre of Economic Policy and National Gas Transmission as project partners.

The core SNZI Onshore project under the IDC programme progressed technical scoping of an onshore CO_2 pipeline to transport captured emissions from Scotland's central belt to St Fergus[66].

These projects include a proposed new power station with carbon capture at Peterhead and carbon capture from existing facilities at the St Fergus gas terminal. The SNZI Onshore scope also included the design of a new 300 MW low carbon hydrogen production facility[xi,67] (Acorn Hydrogen), though this project is currently paused pending additional maturation and investment decisions.

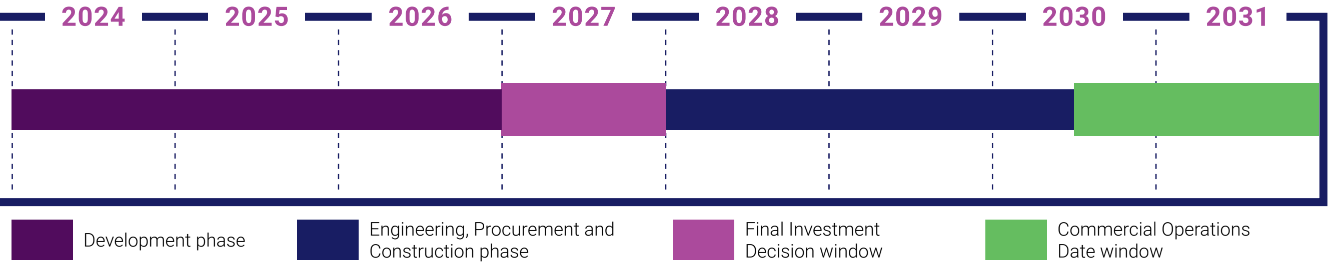
A key component of the SNZI Onshore project involved the potential repurposing of an existing natural gas pipeline that runs from Scotland's Central Belt to North East Scotland, for onshore CO_2 transportation. This NGT-led project, titled "SCO_2T Connect", studied the feasibility of a CO_2 pipeline network to transport the captured emissions from the large industrial emitters in Central Scotland to St Fergus[68]. Prospective users of this transportation facility include the INEOS site at Grangemouth, the Shell and ExxonMobil facilities at Mossmorran[67], and several other industrial capture projects across central and North East Scotland.

xi Although this subproject received IDC funding, the project is not currently being pursued as an active project following the completion of the IDC programme.

Figure 13: SNZI Onshore indicative project timeline

Project Timeline[71]:

Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.



The SNZI Onshore project also progressed the design of viable CO_2 shipping infrastructure. This infrastructure has the potential to support clusters and locations without access to offshore storage by enabling ship-borne CO_2 to be imported[67].

Impact:

Projects explored within SNZI Onshore aim to capture up to 2.9 MTPA[xii] and transport up to 5 MTPA of CO_2[68,69] which will be routed for permanent storage in the North Sea through the infrastructure considered by the SNZI Offshore scope.

The transport infrastructure explored as part of the SNZI Onshore project offers a credible decarbonisation pathway for a large proportion of Scotland's industry, significantly contributing to the country's net zero ambition. Additionally, through CO_2 shipping, the project has the potential to support the decarbonisation of industry in other parts of the UK that do not have access to nearby stores[66,70].

The Scottish cluster could therefore become a significant CO_2 import hub and open economic opportunities for the UK[67].

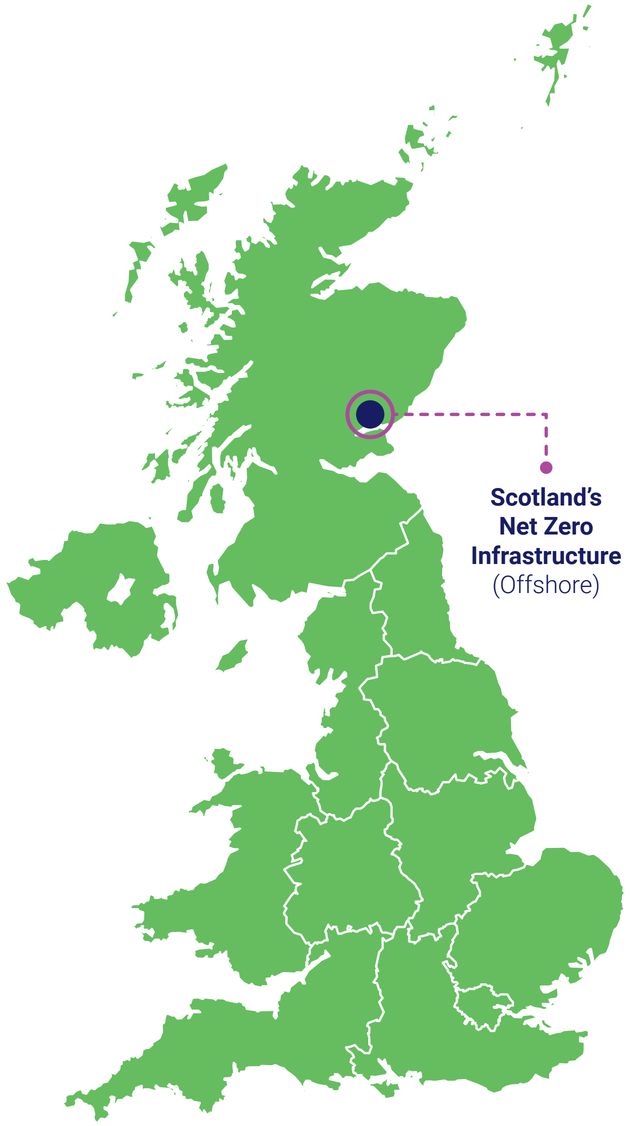
Significant milestones and progress:

SNZI Onshore has achieved the following:

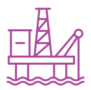
- **progressed technical design:** The technical design work has developed a flexible T&S system with options for emitter tie-ins, varying compressor count, access to multiple storage sites, well count and so on. The successful completion of FEED for the CO_2 capture scope advanced the technical design of the carbon capture facilities at St Fergus gas terminal, whilst the facilities design for SSE's proposed new power station at Peterhead[71], was matured through pre-FEED and has commenced a multi-part FEED.
- **confirmed feasibility of repurposing:** Work to date by National Gas Transmission indicates it is technically feasibility to repurpose their onshore "Feeder" pipelines for CO_2 service.
- **innovated in CO_2 shipping design:** The project development work included the design of a large-cargo medium-pressure CO_2 ship[66]. The design de-risked scale-up of medium pressure CO_2 carriers and has the potential to support the shipping of CO_2 from large emitters in the UK and North West Europe.

xii This capture capacity includes the IDC-funded scope only: CO_2 captured from the Peterhead power station, St. Fergus gas terminal and a blue hydrogen production facility

Scotland's Net Zero Infrastructure (Offshore)
offshore pipeline, subsea and well-related infrastructure to transport and inject CO_2 offshore for long-term secure storage

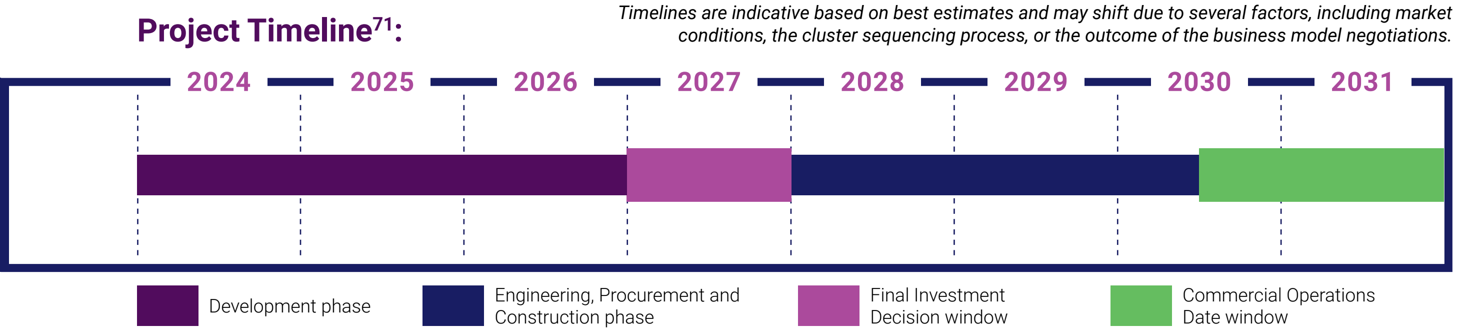


Deployment Project technologies key


Offshore pipelines and subsea CO_2 storage

Scotland's Net Zero Infrastructure (Offshore)

Figure 14: SNZI Offshore indicative project timeline



Overview of IDC-funded scope:

This project progressed the design of the major offshore components of the Scottish industrial cluster, including its offshore pipelines, subsea infrastructure, wells to inject CO_2, and storage sites to inject CO_2. The CO_2 would be from the SNZI Onshore and other emitter projects, transported through the onshore CO_2 pipelines, or received from the CO_2 shipping infrastructure. The CO_2 collected at St Fergus would be routed via a repurposed offshore pipeline to the Acorn storage facilities and later, via a second repurposed pipeline, to the East Mey storage facilities. The infrastructure could offer an initial transport and storage capacity of up to 5 MTPA[69]. However, this is subject to further design development, negotiation with the Government, and subsequent FID.

Impact:

The infrastructure considered by SNZI Offshore enables the decarbonisation of the Scottish cluster as the captured CO_2 emissions within Scotland would be routed to St Fergus for offshore transport and permanent storage[72]. The CO_2 storage capacity could be significantly expanded by developing additional stores in the North Sea, such as East Mey, thereby providing infrastructure to multiple emitters[6,72].

Significant milestones and progress:

SNZI Offshore has achieved the following:

- **refined estimates of storage capacity:** Detailed subsurface and well engineering work was completed, allowing for the development of a reference CO_2 storage capacity case for the combined Acorn and East Mey stores[70]. This was an important initial step in building out the CO_2 stores in the area.
- **developed the technical offshore design:** Throughout the project, the transport & storage system was further de-risked and defined, which included the development of the subsea infrastructure and well scopes[70].
- **validated suitability of Goldeneye pipeline for re-purposing as a CO_2 pipeline:** By inspection of the offshore pipeline, the project concluded that the pipeline could be repurposed for CO_2 transport. This has resulted in a significant value for money and cost reduction opportunity[66,70].

South Wales Industrial Cluster
regional hydrogen production, CO_2 transportation, and new low-carbon collaboration between industry, agriculture, towns/cities and transport

Deployment Project technologies key

Industrial carbon capture technology

CO_2 and H_2 transportation pipelines

Industrial infrastructure

Low-carbon power stations

South Wales Industrial Cluster

Overview of IDC-funded scope:

SWIC's ambition is to decarbonise a significant amount of the emissions from the South Wales industrial and power emitters, reinforced by a comprehensive infrastructure deliverable scheme for hydrogen, CO_2 transportation and shipping. The project is led by RWE and includes Dragon LNG, Shell, and Wales & West Utilities as core project partners.

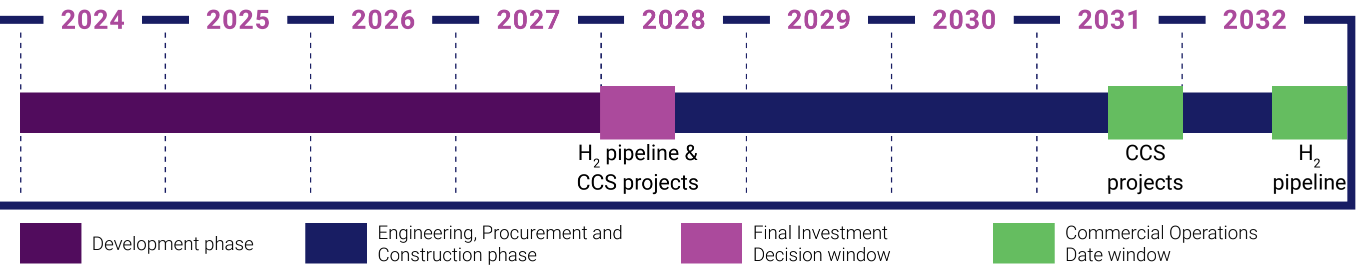
The core project scope under the IDC programme included CO_2 capture from the existing RWE Pembroke power station and a Shell low carbon hydrogen plant. This has evolved with the RWE project now acting as the core anchor for the CO_2 scope following the completion of the IDC programme[xiii]. The captured CO_2 will be transported via infrastructure connections to the 2.5 MTPA liquefaction and shipping facility[73] developed by Shell and Dragon LNG for CO_2 transport. A CO_2 shipping solution is critical for the project as the region lacks nearby geological storage for CO_2[74]. The captured CO_2 will be exported to storage sites that can accommodate shipping for permanent storage.

[xiii] Although the Shell blue hydrogen project received IDC funding, the project is not currently being pursued as an active project.

Figure 15: SWIC indicative project timeline[xv]

Project Timeline[77,78]:

Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.



Although IDC programme included both blue[xiv] and green hydrogen production facilities, the core scope currently progressing is green hydrogen, led by RWE to enable the decarbonisation of local industrial activities[75], and an onshore 130 km pipeline developed by Wales & West Utilities through the HyLine Cymru project. The pipeline will connect low carbon hydrogen production with industrial demand and is sized with a capacity of approximately 8 TWh per year[76].

Impact:

The HyLine Cymru project will provide critical infrastructure to deliver low carbon energy at scale in South West Wales. The 130 km onshore pipeline will run from Pembroke to Port Talbot and provide low carbon hydrogen to support the decarbonisation of heavy industries like cement, paper, steel, mineral wool, chemicals, and food[77]. The pipeline will also unlock renewable generation in the region by providing a route to market for clean energy producers, such as via the 4.5 GW of offshore wind planned in the Celtic Sea[77].

Significant milestones and progress:

SWIC has achieved the following:

- **demonstrated shipping potential:** The studies conducted to date by SWIC have demonstrated a viable approach to utilising an end-to-end shipping solution to transport CO_2[6]. This offers an important opportunity for the UK to develop a commercial CO_2 shipping model that can be replicated globally.
- **progressed technical design:** Both the CO_2 and hydrogen scopes of work have advanced through their development studies. Pre-FEED has been completed, with final reports being issued for the post combustion carbon capture scope of RWE's power station and for Wales & West Utilities H_2 pipeline. This prepares the project for future discussions as part of the cluster sequencing process. Likewise, implementation plans for hydrogen combustion blends of 40% have been issued, and the Pre-FEED is complete for the green hydrogen scope[79].

[xiv] Although the Shell blue hydrogen project received IDC funding, the project is not currently being pursued as an active project.

[xv] CCS projects include the following elements: CO_2 capture project, as well as CO_2 liquefaction and shipping. Although the Shell blue hydrogen project received IDC funding, this project is not included because the project is currently not being pursued as an active project. The timeline refers to the initial phase of CCS deployment at SWIC, which was within IDC scope.

Section 4: The IDC Deployment Projects' contributions towards UK goals

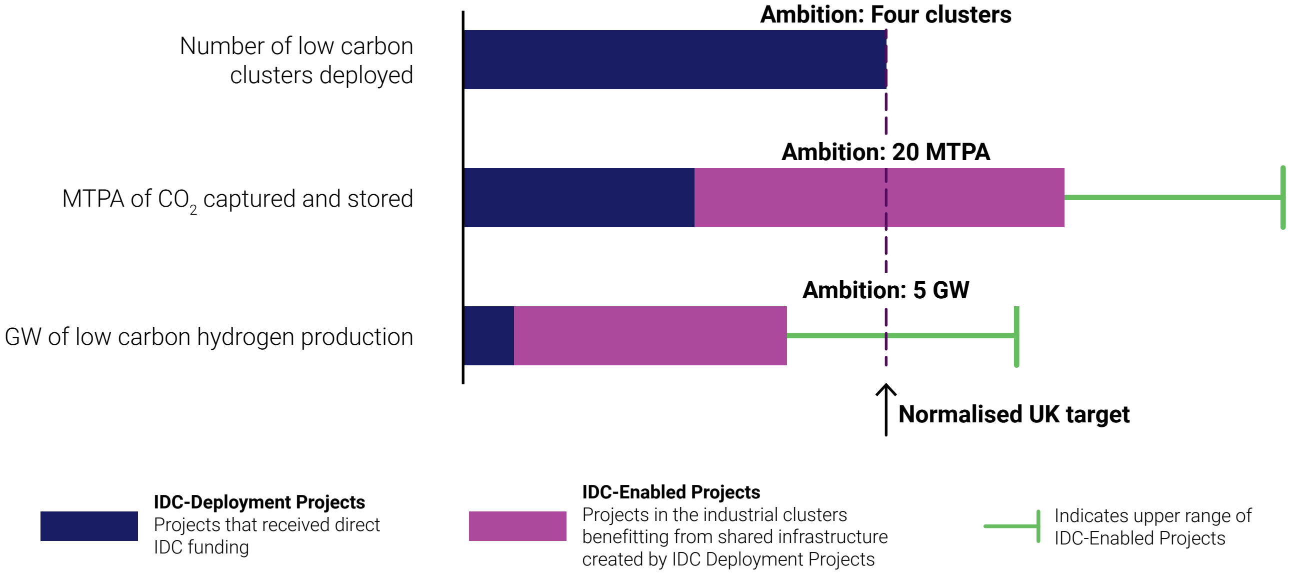
Introduction to the IDC Deployment Projects' contributions

The CCS and hydrogen sectors are key decarbonisation pathways for heavy, energy intensive industries. They are also two of the key building blocks in creating a clean energy system. In pursuit of net zero, the UK has set ambitious 2030 CCS and hydrogen goals:

- deploy four low carbon (CCUS) clusters
- capture 20 to 30 MTPA of emissions, including the power and industrial sector
- deploy 10 GW of low carbon hydrogen production capacity (half of which may be blue hydrogen enabled by CCS)

The contributions from the IDC Deployment Projects and additional projects within the industrial clusters that are enabled by the shared infrastructure developed by IDC Deployment Projects (henceforth IDC-Enabled Projects) towards the UK goals are represented in **Figure 16** below.

Figure 16: Indicative contributions of the IDC Deployment Projects and IDC-Enabled Projects towards the latest UK goals, as of September 2024



The IDC Deployment Projects are on track to help the UK meet its goal of four low carbon clusters by 2030[xvi]. Together with the IDC-Enabled Projects, they can help the UK exceed the lower limit of the CCS capture goal of 20 MTPA by 2030 and deliver 76% of the low carbon hydrogen production goal[xvii].

The following subsections provide further details of the potential impacts of the IDC Deployment Projects towards the UK's net zero ambitions and green growth agenda.

Contribution to the UK's goal for deploying low carbon clusters

In the CCS Net Zero investment roadmap, published in April 2023, the Government set out the approach to deploy two low carbon clusters by 2028, and a further two clusters by 2030[8,80]. Reaching these goals provides a stepping stone to achieving the world's first net zero industrial cluster by 2040.

The cluster sequencing process is leading the deployment of these low carbon clusters. The process is being implemented through two "Tracks", which define the timeline for the development of the different clusters. The cluster sequencing process selected HyNet (covering North West England and North Wales) and East Coast Cluster (Teesside and part of Humber region in England) as the Track-1 clusters in October 2021. Therefore, CCS will be deployed in these clusters first. As a result, some of the corresponding IDC Deployment Projects (HyNet Onshore, HyNet Offshore, NEP and NZT Onshore) were shortlisted projects for the Track-1 clusters. This meant that selected projects could enter negotiations with DESNZ on business model arrangements. The start of these negotiations signalled the UK's commitment to delivering first-of-a-kind CCS projects.

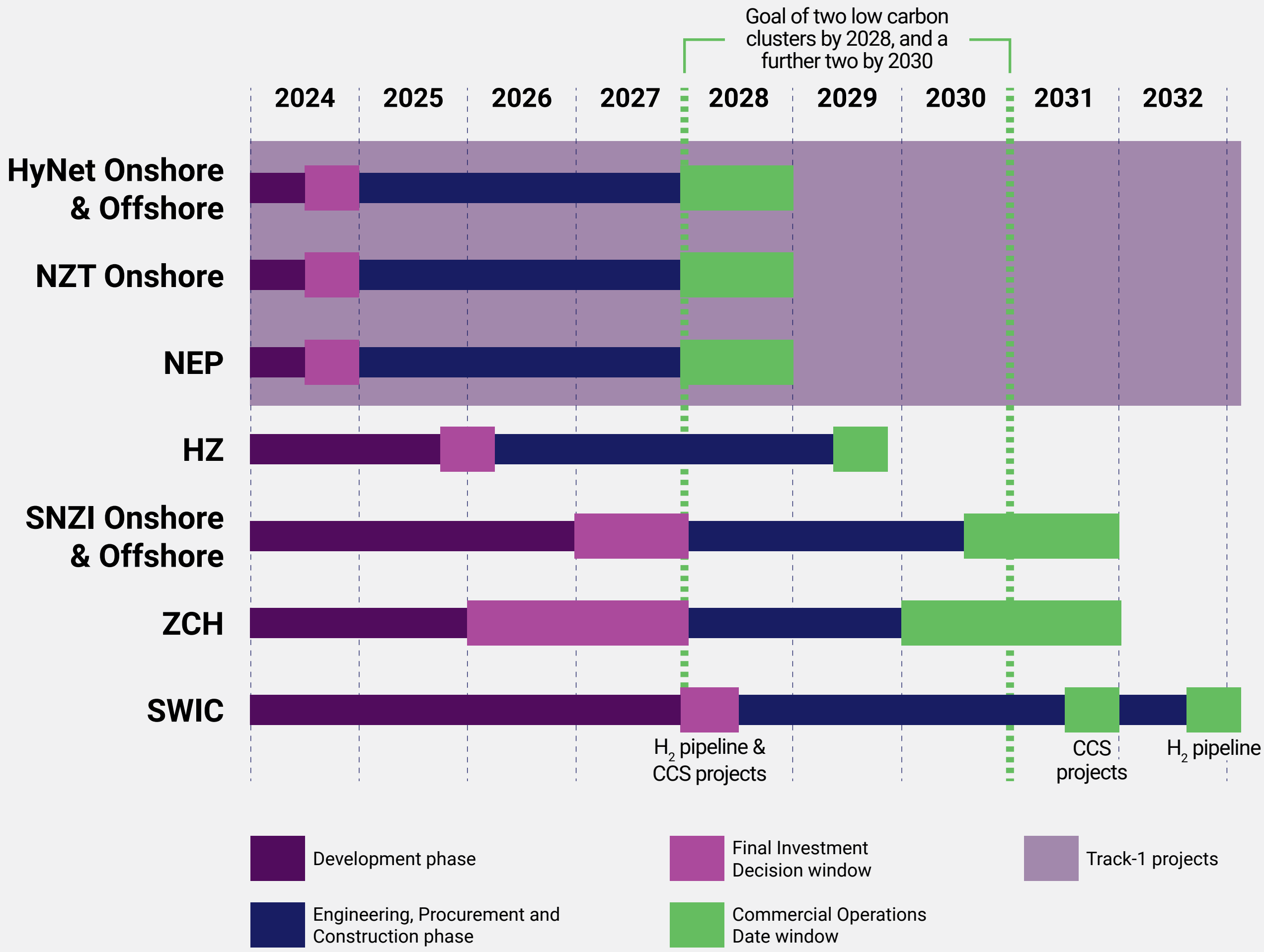
In July 2023, the Government selected two additional clusters as part of the Track-2 process: Acorn (Scotland) and Viking (Humber region in England, with strong links to the IDC's HZ Deployment Project). This was followed by an announcement of a process for the expansion of one of the initial Track-1 clusters (HyNet) in December 2023, with the Government also expressing their commitment to future expansion of the second initial Track-1 cluster (East Coast Cluster)[81]. Through these announcements, specific projects covered within HZ, SNZI Onshore, SNZI Offshore, and ZCH scope are eligible for either Track-2 or Track-1 expansion in the future. Track-2 and Track-1 expansion is expected to follow an updated process based on the learnings from Track-1, with the next stages anticipated to start once FID has been taken by Track-1 clusters (Autumn 2024). Furthermore, the SWIC cluster, not yet formally selected by DESNZ, is also developing a feasible CO_2 shipping solution.

Figure 17 represents the indicative timeline of the IDC Deployment Projects in reference to the UK's goal of deploying two low carbon clusters by 2028 and a further two by 2030.

xvi The IDC Deployment Projects could exceed this goal if the SWIC project timeline could be accelerated to 2030, noting the Government's ambition to deliver clean power by 2030.

xvii UK 2030 5 GW hydrogen production goal (which may be blue hydrogen enabled by CCS).

Figure 17: Indicative timeline of the IDC Deployment Projects to Commercial Operations Date [xviii,xix,xx,xxi]



The selected Track-1 IDC Deployment Projects (HyNet Onshore, HyNet Offshore, NZT Onshore, and NEP) plan to take their initial FIDs in the Autumn of 2024, before advancing to the detailed engineering and construction phase. Their operations are expected to start around 2028, which is in line with the UK's goal to develop two low carbon clusters by 2028. These projects are the most advanced due to being selected in Track-1 of the cluster sequencing process. They have progressed their engineering designs up to the end of the FEED stage, secured or are close to securing the approvals from all regulatory bodies, agreeing or have agreed on Heads of Terms with DESNZ, and are advanced in the process of raising finance.

The five remaining IDC Deployment Projects are progressing their development plans to support the UK's 2030 goals. However, their successful deployment depends on being selected for cluster sequencing and the finalisation of supporting business models. For example, some projects are dependent on the development of business models for Non Pipeline Transport (NPT)[xxii], hydrogen transport (HT), and hydrogen storage (HS). The five remaining IDC Deployment

xviii Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, the outcome of the business models negotiations or the timing of FID.

xix HyNet CO_2 FID and COD are shown. HyNet H_2 FID & COD is expected later as project scope is separated between CO_2 and H_2.

xx CCS projects include the following elements: CO_2 capture project, as well as CO_2 liquefaction and shipping.

xxi Non-Track-1 projects include Track-2, Track-1 expansion, and other clusters not yet formally selected through the cluster sequencing process.

xxii NPT could either be its own business model or integrated into existing business models.

Projects have indicated that these elements are key to being able to progress towards and take positive FIDs, which are estimated to be between late 2025 and early 2028. This puts the Commercial Operations Date (COD) for these projects between mid-2029 and late-2032. The anticipated operation dates show IDC Deployment Projects' development timelines are currently in line with the UK's goal of establishing two additional low carbon clusters by 2030.

This means the IDC Deployment Projects are on track to help the UK meet its goal of four low carbon clusters by 2030[xxiii]. It should be noted that the typical development timeline of a large-scale CCS project is seven to nine years, with half of this time occurring post-FID[82,83]. **Therefore, for a large-scale CCS project to be operational by the end of 2030, it will likely need to take its FID no later than June 2027. This underscores the need for the Government to maintain momentum on progressing these projects towards their targeted FID dates to achieve the UK's 2030 goal.**

The Phillips 66 HZ Deployment Project requires a shutdown of the FCC unit, in order to tie-in the capture plant. The project has therefore been developed on the basis of installing connections during the 2028 FCC maintenance shutdown event; this allows for the work to be done with no additional shutdown-related costs (lost operating margin and shutdown costs). This maintenance event occurs once every five to six years. Due to the timing of the UK's industrial decarbonisation programme, tie-ins during the planned 2028 maintenance event may no longer be an option.

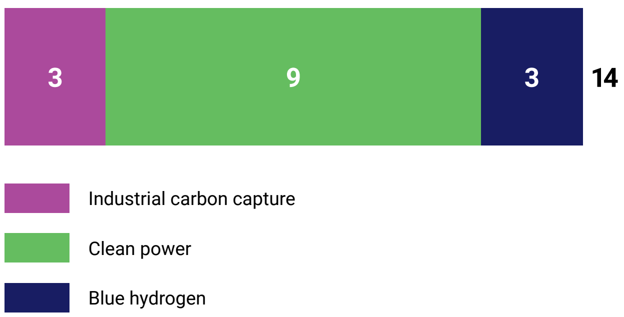
Therefore, the project team is currently investigating the technical, safety, and business impacts of an additional FCC outage, if needed. This would enable the project to maintain Track-2 eligibility and support government CO_2 reduction goals.

xxiii The IDC Deployment Projects could exceed this goal if the SWIC project timeline could be accelerated to 2030, noting the Government's ambition to deliver clean power by 2030.

Contribution to the UK's goal for capturing and storing CO_2

The IDC Deployment Projects will achieve emissions reduction benefits in support of the UK's industrial decarbonisation efforts. The IDC Deployment Projects could capture and store up to 14 MTPA of CO_2[xxiv,xxv]. As illustrated in **Figure 18**, most of the anticipated carbon capture capacity of the IDC Deployment Projects (approximately 65%) is associated with clean power projects from the NZT Onshore, HZ, SNZI Onshore, and SWIC. The remaining 35% is from low carbon hydrogen and industrial carbon capture projects.

Figure 18: Breakdown of carbon capture capacities of the IDC Deployment Projects in MTPA by type of application[xxvi]



The IDC Deployment Projects will support the UK's aim to capture and store 20 to 30 MTPA of CO_2 by 2030 as it transitions to a net zero economy. By 2030, the IDC Deployment Projects could capture and store up to 11 MTPA of CO_2, thereby achieving 55% of the UK's lower limit CCS goal of 20 MTPA by 2030[xxvii,xxviii].

The IDC Deployment Projects, once realised, would develop shared CO_2 transport and storage infrastructure for the industrial cluster where they are based (e.g., Teesside, Humber, North West, and Scotland). The shared infrastructure is designed with spare capacity such that it can accommodate demand from future carbon capture and blue hydrogen projects. This would unlock additional CO_2 capture capacity within the industrial clusters **(Figure 19)**. The low carbon projects enabled by the shared infrastructure developed by the IDC Deployment Projects are defined as "IDC-Enabled Projects". The methodology for calculating the CCS capacity of the IDC-Enabled Projects is detailed in **Appendix 2**.

xxiv Calculated based on the limiting factor (infrastructure component) across the CCS value chain. See **Appendix 2** for additional details on how capture and storage estimates were developed for this report.

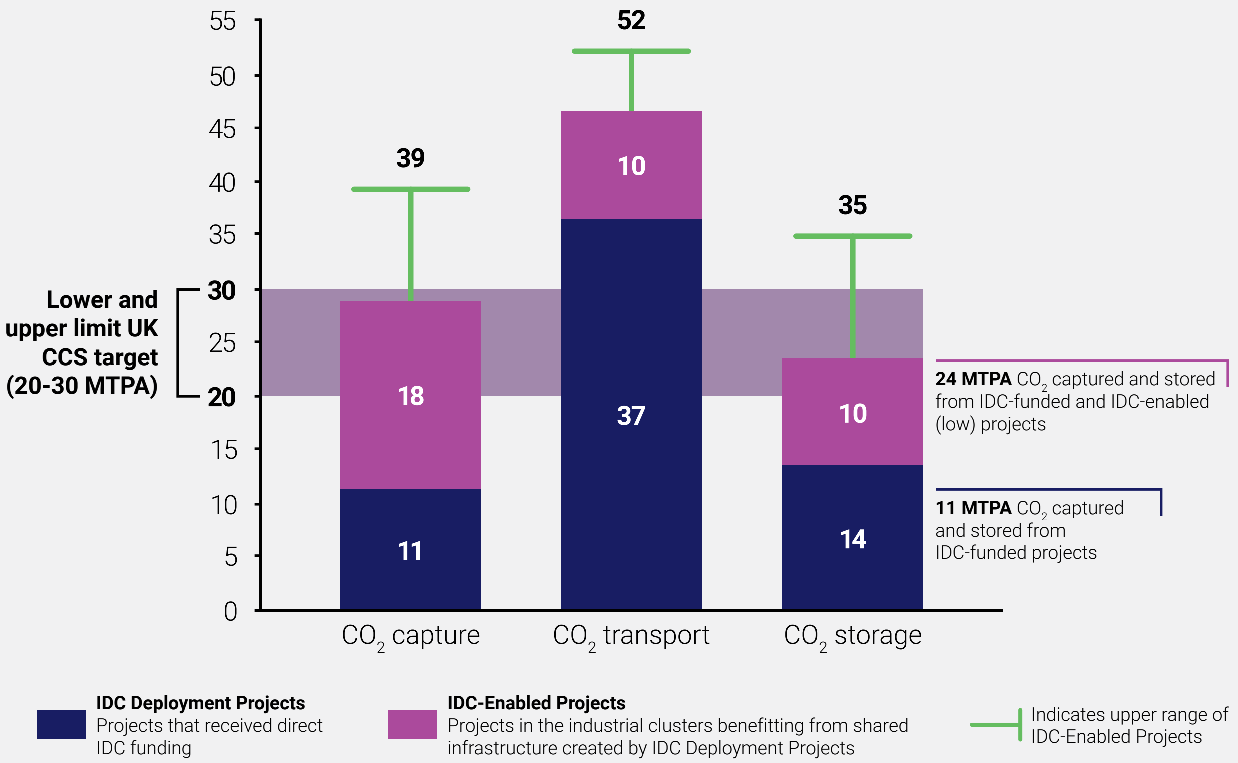
xxv The contribution from the IDC Deployment Projects is dependent on projects progressing through the development lifecycle to the operational phase. The contribution could be lower if projects do not advance forward or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

xxvi Values do not sum due to rounding.

xxvii Calculated based on the limiting factor (infrastructure component) across the CCS value chain. See **Appendix 2** for additional details on how capture and storage estimates were developed for this report.

xxviii The contribution from the IDC Deployment Projects is dependent on projects progressing through the development lifecycle to the operational phase. The contribution could be lower if projects do not advance forward or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

Figure 19: CO_2 capture, transport, and storage capacity by 2030 of IDC Deployment Projects and IDC-Enabled Projects in MTPA[xxix,xxx,xxxi]



For CO_2 capture capacity, the IDC-Enabled Projects could contribute an additional 18 MTPA by 2030. Nearly 80% of this anticipated carbon capture capacity is associated with clean power (38%) and blue hydrogen production (39%) projects. Together, IDC Deployment Projects and IDC-Enabled Projects could contribute approximately 29 MTPA in CO_2 capture capacity by 2030.

The additional capture capacity delivered by the IDC-Enabled Projects will be from abating emissions through a range of processes. These include industrial carbon capture, energy-from-waste, bioenergy with carbon capture, clean power, and blue hydrogen production. The additional projects are primarily concentrated in the Humber and Teesside industrial clusters, which are dominated by the refining, chemicals, and iron & steel sectors[xxxii,5].

xxix Includes Viking CCS as Humber projects will utilise the regional onshore CO_2 pipeline and connect to either NEP or Viking CCS transport and storage system.

xxx Values do not sum due to rounding.

xxxi The contribution from the IDC Deployment Projects and IDC-Enabled Projects are dependent on projects progressing through the development lifecycle to the operational phase. The contribution could be lower if projects do not advance forward or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

xxxii Refer to **Appendix 2** for the full breakdown of carbon capture capacity projects by region included within IDC-Enabled projects as part of this analysis.

For CO_2 transport capacity, most of the transport infrastructure in the industrial clusters has been designed with future capacity in mind. This prepares it for when new low carbon projects need to connect to the CO_2 network.

For example, the offshore CO_2 pipelines connecting the Teesside cluster to the NEP storage site are designed to transport 10 MTPA. In comparison, the IDC Deployment Project (which includes NZT Onshore) and IDC-Enabled Projects at Teesside could capture up to 6.4 MTPA, resulting in approximately 3.6 MTPA of additional transport capacity for future emitters to benefit from the shared infrastructure. A similar trend is observed in the Scotland and North West clusters, where the transport capacity exceeds the expected capture capacity of IDC Deployment Projects by 2030.

Finally, for CO_2 storage capacity, the inclusion of the IDC-Enabled Projects increases the potential storage capacity from 14 MTPA to 24 MTPA by 2030. This represents a 71% increase relative to the capacity created by the IDC Deployment Projects. This is driven by increased storage capacity from the Viking CCS project.

As part of this analysis, Viking CCS is considered an IDC-Enabled Project because the HZ IDC Deployment Project is a 'cluster member' of Viking CCS[xxxiii,58]. The capture projects in HZ (at VPI and Phillips 66 Limited facilities) are likely the first capture projects of Viking CCS that will be operational, thus playing an important role in realising that project. Furthermore, the Viking store has the potential to link to a range of other emitters in the Humber region, increasing its contribution to transporting and storing CO_2.

[xxxiii] Core project lead of Viking CCS, Harbour Energy, is also a non-funded partner of IDC.

Combined, the IDC Deployment Projects and IDC-Enabled Projects could contribute up to 24 MTPA of capacity for capturing and storing CO_2 by 2030. This equates to 120% of the UK's lower limit CCS goal of 20 MTPA by 2030[xxxiv]. There is potential for this capacity to be higher, though the CO_2 storage capacity is a potential bottleneck to bringing additional capture projects online by 2030. **Figure 19** highlights this disparity between CO_2 capture, transport, and storage capacity by 2030.

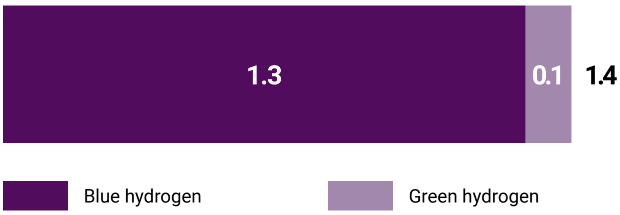
If the development of around 5 to 6 MTPA of additional storage capacity is accelerated, the UK could potentially capture and store very close to the upper goal of 30 MTPA of CO_2 by 2030. This acceleration would be especially helpful in the Humber and Teesside clusters, where the analysis shows capture capacity will exceed the storage capacity of IDC Deployment Projects and IDC-Enabled Projects by 2030. However, it is unlikely that additional CO_2 storage development will take less than five years to bring online, and therefore delivering additional storage capacity may not be possible by 2030.

The NEP and HyNet Offshore IDC Deployment Projects are already exploring opportunities to bring an additional 6 and 5.5 MTPA in CO_2 storage capacity online, respectively. This is through the next expansion phase of their projects and is aligned with cluster sequencing expansion processes, where additional emitters will be selected.

Contribution to the UK's goal for producing low carbon hydrogen

Hydrogen is another key component of the UK's plans for industrial decarbonisation. The IDC Deployment Projects play a significant part in this as they could produce up to 1.4 GW of low carbon hydrogen[xxxv]. This is primarily through blue hydrogen production, which accounts for 92% of IDC Deployment Projects total hydrogen production capacity **(Figure 20)**.

Figure 20: Breakdown of low carbon hydrogen production capacities in GW of IDC Deployment Projects by technology type



0.7 GW of this production capacity is expected to be commissioned by 2030, of which 0.6 GW is from blue hydrogen production **(Figure 21)**. This represents 12% of the UK's non-green hydrogen production goal of 5 GW by 2030 laid out in the UK's Hydrogen Strategy (which may be from blue hydrogen enabled by CCS)[xxxv,xxxvi]. This could increase to 26% if additional IDC-funded blue hydrogen projects are resumed[xxxvi] and their development accelerated to meet 2030 COD. The IDC supported the development of these blue hydrogen projects, but they are currently paused by their developers following the completion of the IDC programme due to market conditions and slower than anticipated progress in the development of the hydrogen business models.

xxxiv Capacity of the CCS value chain is defined as the volume of CO_2 that can be captured, transported, and stored in a CO_2 store. The capacity of the value chain is dictated by the component of the value chain (capture, transport & storage) that has the lowest capacity.

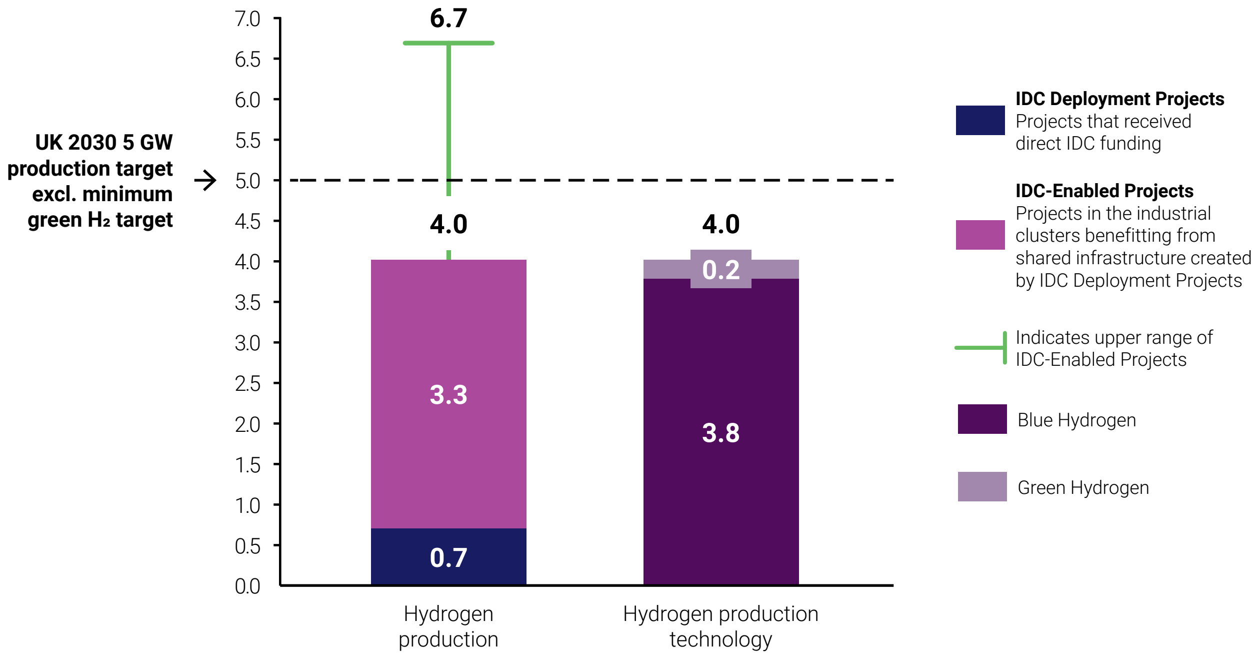
xxxv The contribution from the IDC Deployment Projects is dependent on projects progressing through the development lifecycle to the operational phase. The contribution could be lower if projects do not advance forward or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

xxxvi This excludes the SNZI Onshore and SWIC blue hydrogen projects, which is currently not being pursued as an active project following the completion of the IDC programme.

When accounting for projects enabled by the shared infrastructure built by the IDC Deployment Projects, the low carbon hydrogen production capacity increases significantly.

Combined, the IDC Deployment Projects and IDC-Enabled Projects could contribute approximately 4.0 GW of low carbon hydrogen production by 2030. Of this production capacity, blue hydrogen contributes 3.8 GW. This represents 76% of the UK's non-green hydrogen production goal of 5 GW by 2030. The increase in blue hydrogen production capacity mainly stems from the Humber and North West industrial clusters.

Figure 21: Low carbon hydrogen production capacity by 2030 of IDC Deployment Projects and IDC Enabled Projects in GW [xxxvii]



xxxvii The contribution from the IDC Deployment Projects and IDC-Enabled Projects are dependent on projects progressing through the development lifecycle to the operational phase. The contribution could be lower if projects do not advance forward or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

Blue hydrogen production relies on CO_2 transport and storage infrastructure to ensure emissions released while producing hydrogen are captured and stored. Therefore, the availability of CO_2 storage is a critical factor in achieving the UK's 2030 hydrogen production goals. Where CO_2 stores are projected to be oversubscribed, blue hydrogen projects will be in competition with other CO_2 capture projects to connect to CO_2 storage sites.

The Humber region is expected to contribute 2.0 GW of blue hydrogen production capacity through ZCH and IDC-Enabled Projects. This equates to an approximate CO_2 capture capacity of 4.6 MTPA. The total expected capture capacity of the ZCH and IDC-Enabled Projects in Humber is approximately 11.9 MTPA by 2030 (including blue hydrogen projects), while only 10 MTPA of storage capacity is expected to come online by that time via Viking CCS project.

Therefore, any delays in bringing CO_2 storage capacity online will likely impact the UK's ability to meet its 2030 low carbon hydrogen production goal and the rollout of a hydrogen economy, which is one of the main levers for industrial decarbonisation. This reinforces the importance of industry and government working together to develop and bring sufficient CO_2 storage capacity online by 2030.

Contribution to UK economy and broader societal benefits

The IDC Deployment Projects' contributions are not limited to their environmental benefits. As large, multibillion-pound infrastructure developments, they will bring about wider economic and social benefits as labour, goods, and services are purchased in support of the design, assessment, construction, and operation of projects[xxxviii].

Socioeconomic impacts of the IDC Deployment Projects are captured using two main measures: employment and gross value added (GVA). Employment captures the potential of IDC Deployment Projects to support numerous jobs across occupations such as research, engineering, and construction. GVA captures their potential to boost the UK economy through increased productivity and growth in low carbon industry sectors.

This report combines impact estimates from individual IDC Deployment Projects into a UK-wide view of potential employment and GVA supported across all nine IDC Deployment Projects. Both direct and indirect effects are considered through all phases of projects[xxxix] and presented in **Figure 22**. Together, the nine IDC Deployment Projects have the potential to support up to £35 billion in GVA and 24,000 jobs per year through 2050[xl].

However, there is significant variation in economic impacts between the construction and operations phases of project lifecycles. Employment and GVA potential are frontloaded during construction, which is expected to be

[xxxviii] See **Appendix 3** for additional details on how project expenditure has been modelled to affect economic output and employment in the UK economy by IDC Deployment Projects.

[xxxix] Direct and indirect employment is inclusive of 'direct' jobs that occur directly related to project investment (e.g., a welder hired to build a component of a project pipeline), as well as 'indirect' jobs that occur due to changes in the upstream supply chain with businesses purchasing from one another (e.g., employment of a metal wholesaler that supplies raw materials to the project).

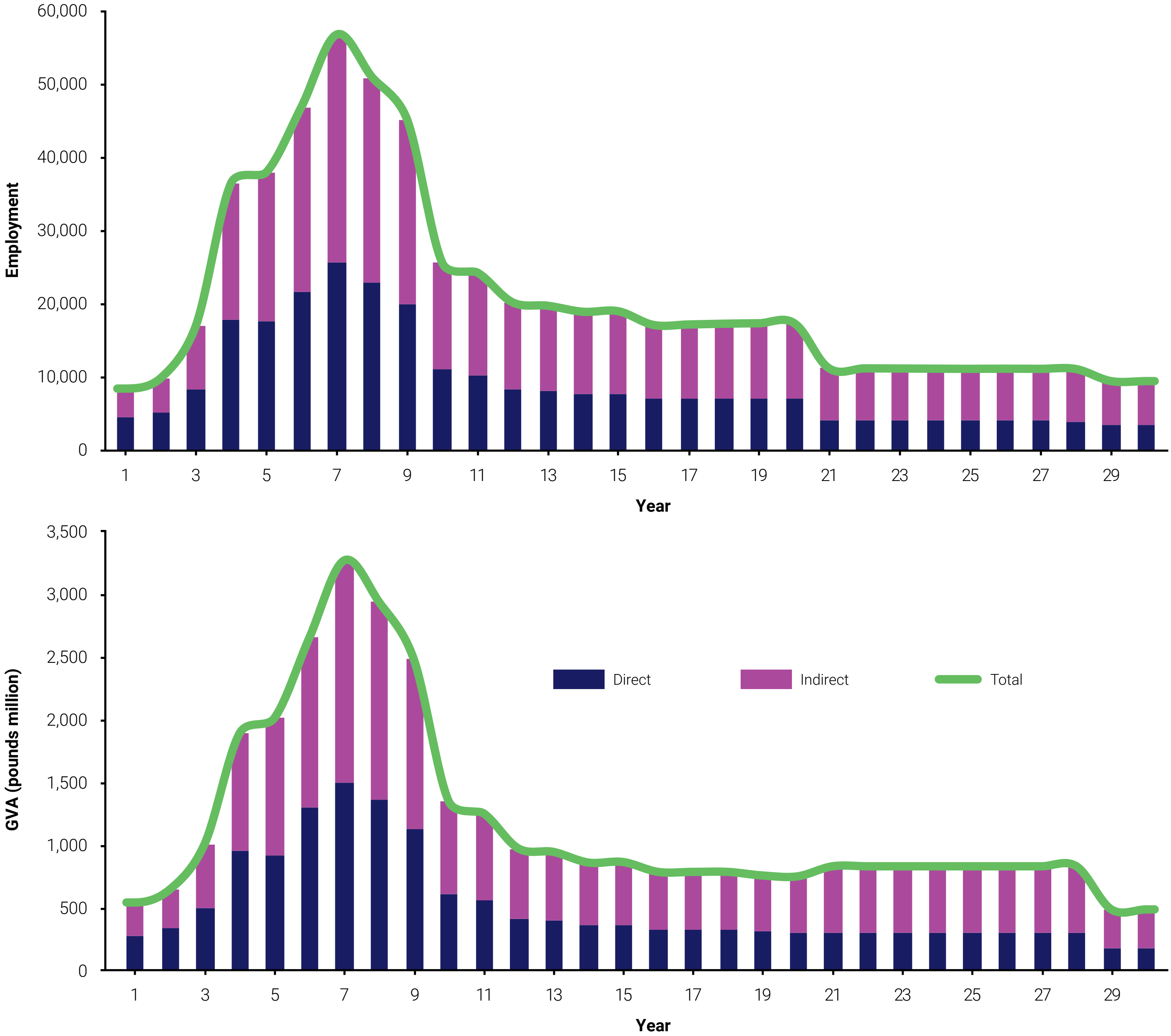
[xl] Employment impacts are calculated in "job years." One "job year" is defined as one job, lasting one year. It is not a count of the number of positions supported by projects (e.g., if a project requires one pipe-fitter role that lasts for five years; this would be characterised as support of five job years by the project). Average annual employment impacts are based on job years. They provide an indication of how many jobs are expected in any given year of the period modelled. It is calculated by taking the job years figure and dividing it by a given number of years modelled to obtain an average number of jobs per year.

completed by 2030 for most projects. **The IDC Deployment Projects are expected to support around 50,000 jobs per year and £20 billion GVA in total during project construction[xli].**

Impacts are expected to peak at nearly 57,000 jobs and £3 billion GVA by the end of the 2020s, when most of the IDC Deployment Projects are expected to be in their construction phases. More than half of total employment and GVA impacts manifest by the start of the 2030s, when most projects expect to be transitioning into operations.

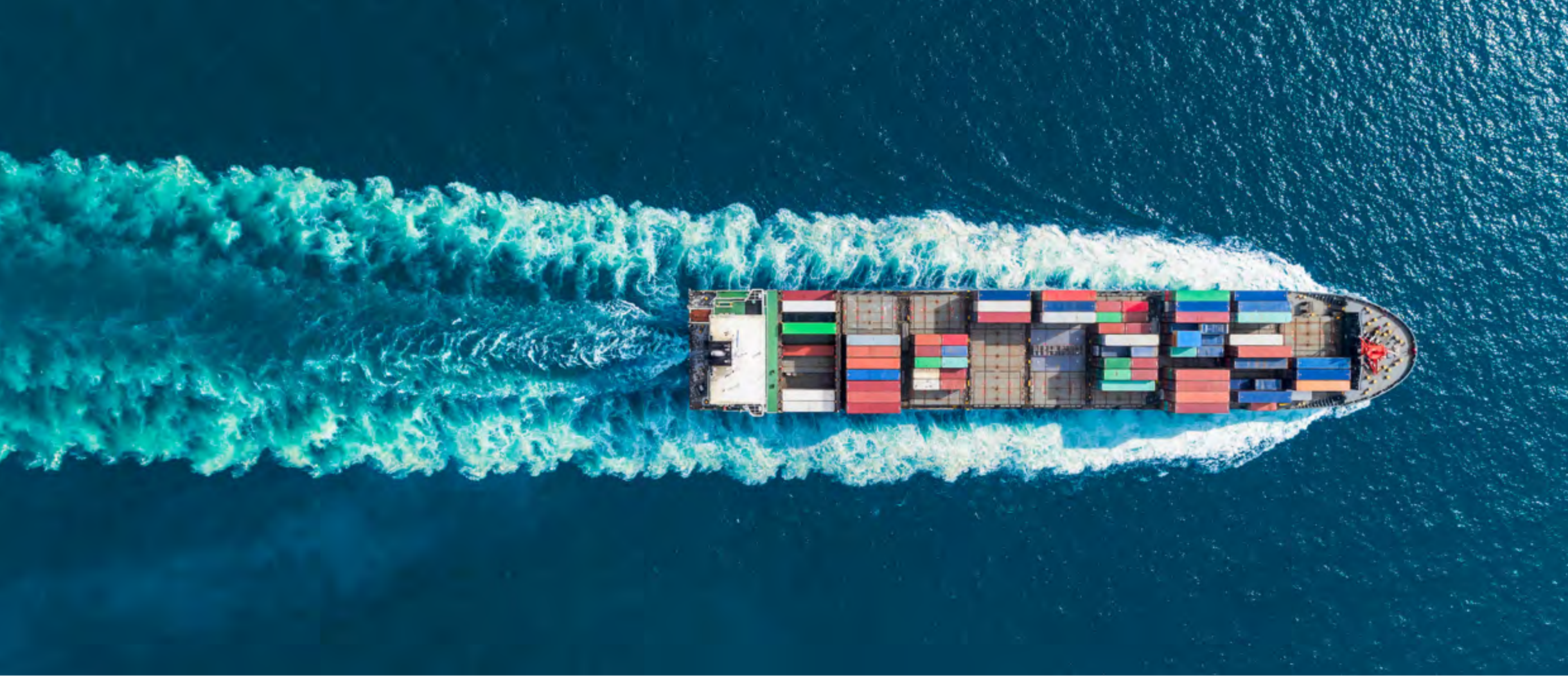
While the average operations period modelled by projects is more than double the length of construction periods, the phase supports lower cumulative impacts overall. In their operational phases, the IDC Deployment Projects expect to support £15 billion GVA up to 2050.

Figure 22: Potential IDC Deployment Projects employment and GVA impacts over a thirty-year period including projects construction and operation[xlii]



xli Includes direct and indirect effects.

xlii Indicative thirty-year periods are modelled as exact timings of project construction and operations phases are in flux and subject to change based on ongoing project development and market conditions.



The IDC Deployment Projects support wider socioeconomic benefits, beyond employment and GVA.

While the IDC Deployment Projects have the potential to deliver significant economic impacts, the magnitude depends on external market conditions. For example, one important factor is the extent to which the UK can allocate labour and secure supply chains. The constrained supply chain is one of the primary challenges identified by the IDC Deployment Projects, which is discussed in detail in **Section 5.**

The IDC Deployment Projects also acknowledge the criticality of the UK supply chain's ability to accommodate demand for labour and services in their own analyses. For instance, SNZI estimated economic impacts based on the assumption that up to 43% of the project's spend would take place overseas[84]. While increasing expected domestic spend would increase estimates of UK employment and GVA impacts, the IDC Deployment Projects face real challenges in doing so. Project partners have acknowledged that workforce constraints in the local market have already resulted in projects exploring alternative strategies such as outsourcing to Asia[85].

Compounding the challenge, the IDC Deployment Projects anticipate that supply chain strain will grow as the global pipeline of hydrogen and CCS projects expands. Projects already report a lack of sufficiently experienced and sized contractors to construct new hydrogen and CO_2 pipelines. Related external research from the University of Strathclyde has studied how the necessarily concurrent timing of projects could limit the extent to which the UK could capture the full economic potential of developing a CO_2 T&S sector[86].

These considerations highlight an opportunity for government and industry to identify ways to secure domestic spend on goods and services as the UK builds out its CCS and hydrogen capacity. Some IDC Deployment Projects have highlighted UK content goals as a potential policy tool to address risks related to this issue and incentivise investment in the UK supply chain. The opportunity is explored in greater detail in **Section 5** and **Section 6**.

The IDC Deployment Projects support wider socioeconomic benefits, beyond employment and GVA. Their contributions to workforce and skills development, community investment, and equity, diversity, and inclusion (EDI) can help bring about a just net zero transition – one in which all workers can participate in, and benefit from, the UK's new green economy. Notable efforts to achieve these outcomes include:

- **HyNet's** plans for a "HyNet Skills Academy" to enable workforce development and regional capability to support its projects.
- **bp's Project Enthuse**, which has worked to increase Science, Technology, Engineering and Mathematics (STEM) educator capacity in ten Teesside primary schools around where NZT Onshore and NEP projects are based.
- **In the Humber**, Equinor is engaging with schools and colleges in the region to promote STEM subjects and careers in the energy industry. Equinor are a major sponsor of the Ron Dearing University Technical College in Hull and contribute to the curriculum.
- **SNZI** project members developed and adopted an environmental and social responsibility charter to outline their commitment to EDI. It specifies targeted objectives to help ensure that good governance remained a priority for members throughout the project. These objectives include points like supporting a diverse workforce for all project elements, promoting equal opportunity and non-discrimination, and fostering occupational health and wellbeing.

Fostering equitable growth is particularly relevant for the IDC Deployment Projects. The regions they call home have experienced disinvestment as longtime industrial anchors have moved away. Successful delivery of the IDC Deployment Projects offers opportunities for revitalisation, fighting the trend of economic stagnancy seen over the last few decades[87]. As the IDC Deployment Projects move beyond planning into construction and operations phases, their contributions to their communities and broader regions will continue to grow.

WIDER CLUSTER BENEFITS ENABLED BY IDC DEPLOYMENT PROJECTS

IDC Deployment Projects are situated at the centre of the decarbonisation efforts of larger industrial clusters. These projects serve as critical infrastructure components for their regions, with potential to deliver wider economic and societal benefits across the value chain beyond their individual scopes. These 'enabling' impacts move the UK closer to its decarbonisation targets, while supporting equitable growth and a just transition to net zero.

Meeting net zero goals

A linchpin for wider industrial cluster decarbonisation, the foundation of CCS infrastructure established by IDC Deployment Projects will support the delivery of four CCS clusters by 2030 and is a stepping stone towards achieving the world's first net zero cluster by 2040. Additionally, the IDC Deployment and IDC-Enabled Projects will significantly contribute towards the UK goals of capturing and storing 20 to 30 MTPA of CO_2 and producing 5 GW of low carbon hydrogen by 2030[xliii], which are crucial milestones to reach net zero by 2050.

Driving clean growth and inward investment

The IDC Deployment Projects will be a catalyst for clean growth. By demonstrating cost-effective decarbonisation at scale, they show the UK is ripe for investment and is a harbinger of the clean growth opportunities to come.

Protecting jobs and developing skills

The IDC Deployment Projects offer an opportunity to revitalise the UK's industrial heartlands by supporting jobs that would otherwise be at risk while also investing in retraining and skills development to ensure full participation in the new, green economy.

Enhancing energy security

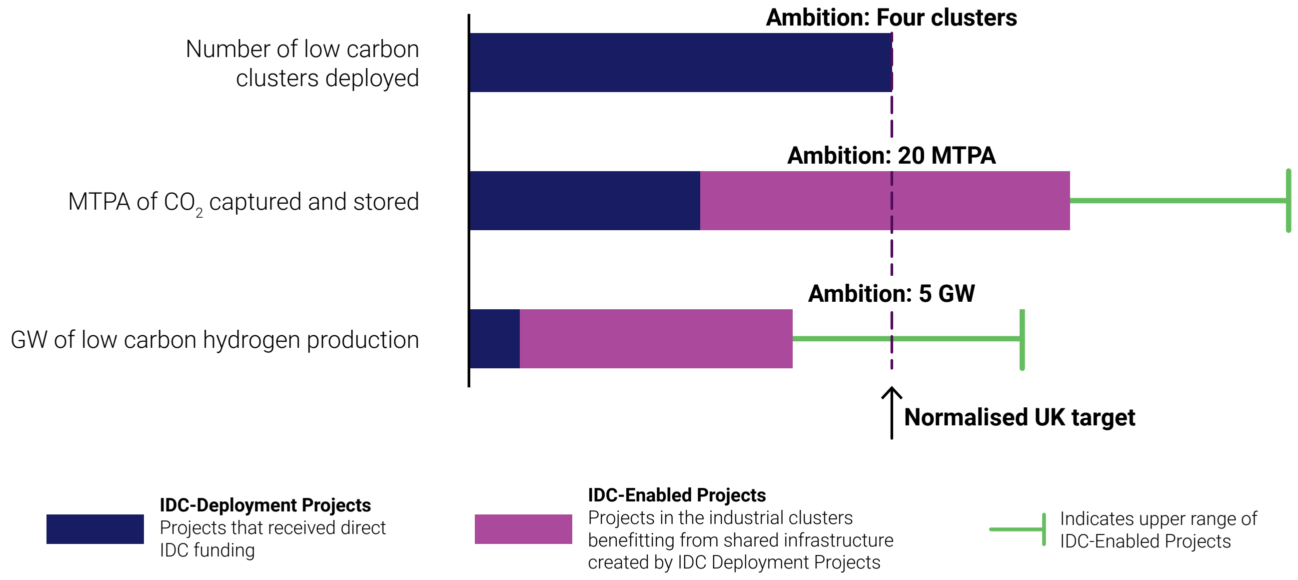
Decarbonised power facilities may soon become widespread as others follow the path set by the IDC Deployment Projects, providing flexible low carbon stable power to the UK energy system.

Nurturing innovation and supply chains

The innovative technologies and applications pioneered by these first-of-a-kind projects offer the opportunity to scale CCS and hydrogen technologies and develop human capital with technical know-how. Dedicated efforts to secure domestic spend on goods and services on these projects will nurture supply chain opportunities at home and abroad.

Growing international trade and exports

The development of extensive CO_2 and hydrogen networks can bring long term economic opportunities to the UK such as importing CO_2 for storage, exporting hydrogen to Europe or new production pathways (e.g., synthetic fuel or ammonia production).



The additional decarbonisation infrastructure enabled by IDC Deployment Projects represent billions of pounds of additional investment in the UK's CCS and hydrogen production capacity. This translates to tens of thousands of employment opportunities and billions of pounds of value added beyond what IDC Deployment Projects themselves are poised to deliver

xliii UK 2030 5 GW hydrogen production goal (which may be blue hydrogen enabled by CCS)

Section 5: The challenges faced by and learnings from the IDC Deployment Projects

Developing a first-of-a-kind project is exciting but challenging. There is no clear path to follow. There is no one ahead to learn from. The IDC Deployment Projects have had to figure it out as they go, accepting the ambiguity and embracing the difficulty of being first.

Each of the nine IDC Deployment Projects is charting their own development journey and learning along the way. While alike in scale, there are considerable differences between the projects. The projects are in different regions with different geographic specificities, make use of different technologies, and have different delivery timelines. Despite these differences, however, they have faced similar challenges along the way.

This section presents the key challenges and lessons learnt from the IDC Deployment Projects in the hope that future CCS and low carbon hydrogen projects can have a head start. The information in this section comes primarily from interviews and workshops with IDC Deployment Project stakeholders and documentation on IDC Deployment Projects.

Sharing these lessons learnt aligns with UKRI's IDC ethos of operating on a collaborative basis through knowledge sharing. These lessons learnt provide an opportunity for future projects to learn from the experiences of these frontrunner projects. By incorporating this knowledge into their projects, future projects can hopefully deliver in a more efficient manner.

While insights from the IDC Deployment Projects are most relevant for project developers looking to pursue low carbon projects in the UK, as well as regulators and policymakers building out the UK CCS sector, these learnings may also be helpful for a broader global audience. First-of-a-kind CCS and low carbon hydrogen projects are likely to face similar challenges regardless of jurisdiction once location-specific policy and regulatory context has been accounted for.

The key challenges and lessons learnt outlined in this section are organised into five themes. These themes and their sub-themes are shown in **Figure 23**.

Figure 23: Overview of key themes and sub-themes of the challenges faced by the IDC Deployment Project

1 TECHNICAL

Technology selection: Challenges associated with novel technology, identifying providers, and integration with existing technology.

System design: Impact of evolving decarbonisation strategies, demand for T&S, and CO_2 specifications on system requirements.

2 REGULATORY

Policy uncertainty: Need for clarity on cluster sequencing, H_2 strategy, and associated timelines.

Business model: Gaps and uncertainty in business models.

3 PROCUREMENT

Supply chain: Risk of supply chain constraints and possibility of delays or shortages.

Tendering: Lack of experience among contractors and procedural hurdles to finalizing contracts.

4 PERMITTING

Process: Lengthy and inflexible process, exacerbates by a large backlog of applications.

Knowledge and resource gap: Lack of resources to adequately process applications due to first-of-a-kind nature of projects.

5 EXECUTION

Collaboration & coordination: Collaboration, sequencing alignment and interdependencies across projects and sub-projects.

Project delivery: Challenges of aligning schedules across work in order to enable effective delivery.

Technical challenges and lessons learnt

Delivering CCS at the scale required to meet the Government's net zero goal is a large technical undertaking that is new for most companies. Players across the value chain are learning as they mobilise, continually developing the technical competencies required to deliver the first wave of low carbon projects. This is particularly true when it comes to selecting the most effective technologies and understanding how best to deploy CO_2 capture solutions into existing processes.

Technology selection

Challenges: The IDC Deployment Projects had to choose between different carbon capture technology solutions and technology providers as they developed their technical design. Given the market is nascent, some projects found it difficult to find information on the range of technology options available. Others found it challenging to understand which technology was best suited for their project needs, given there are few, if any, comparable examples for their use cases. The high upfront licencing costs for proprietary information also acted as barrier for some projects, impacting their ability to comprehensively evaluate options against each other.

Developers struggled to scrutinise the true capability of carbon capture technology licensors to deliver solutions that could meet the scale required by the IDC Deployment Projects, as in many cases, only smaller-scale installations had previously been deployed. These challenges also applied to hydrogen technologies, as projects struggled to understand the full capability of licensors' packages, such as if they could provide 100% hydrogen ready turbines. Having access to a 100% hydrogen ready turbine system was especially important for developers who were looking to future proof their chosen technology and system design. A lack of reliable and comparable cost figures also made it difficult for the IDC Deployment Projects to accurately estimate the costs associated with decarbonising through CCS or fuel switching to hydrogen.

The challenges faced in selecting the most effective capture technology increased the perceived risk imbalance between technology providers and project developers. Given the operational risk lies with developers within the business models, projects selected proven technologies over more innovative solutions. Proven technologies are more likely to provide performance guarantees which is critical to decision making within the current business model framework, given any operational downtime will impact revenues.

Consequently, the cluster sequencing process is indirectly disincentivising the use of more innovative capture solutions that may have driven cost and efficiency gains. Given the scale of decarbonisation needed through CCS, a trade-off that favoured the certainty provided by established technologies was made within the business model development. It is important that other mechanisms are developed to help innovative solutions scale. Having a wide range of technologies available will be key to establishing a mature CCS market.

Lessons learnt:

- close collaboration with other developers within the cluster improved understanding of available technology options. For example, the HZ projects shared technical expertise and knowledge as they progressed through technology optioneering. This led to them independently select the same provider to execute their FEED studies.
- pilot-scale projects would be more appropriate for encouraging innovation and accelerating newer technologies towards a position where they could be compatible with the pace of the CCS rollout required by the UK's net zero goals.
- projects should be rigorous and systematic in assessing technical risks to delivery and develop a technology maturation plan where needed to futureproof and mitigate risks from any novel technology approaches pursued.

System design

Challenges: The use of capture technology within isolated plants is well-proven globally. The challenge IDC Deployment Projects have faced is how to embed capture plants into a wider system encompassing multiple emitters and CO_2 T&S. These are highly integrated projects with interdependencies between different value chain components. System design decisions made by individual projects can therefore impact multiple players across the value chain. This can lead to significant rework and create uncertainty if design decisions are not harmonised and coordinated.

T&S companies have faced system design challenges due to the lack of certainty on which emitters would join the CO_2 or hydrogen network, where they would connect to the network, and what network capacity they required. This directly impacted how best to size and design pipeline and storage infrastructure. The lack of clarity from customers was partly due to some network users being unwilling or unable to share specifics due to commercial sensitivities. Other network users, hydrogen producers in particular, struggled to provide clarity on volumes as they were not clear on their own system designs. As customer project definitions improved, T&S companies had to redesign their systems, creating rework, which extended timelines and resulted in additional DEVEX spend.

T&S network users have similarly faced challenges due to a lack of certainty relating to CO_2 T&S compositional specifications and T&S system design. Many T&S systems have had to iterate CO_2 specifications following studies conducted on their CO_2 store's geological requirements. Changes in specified impurity limits meant emitters had to redesign parts of their capture plants to ensure that the CO_2 captured will meet the T&S network's entry specifications. This resulted in additional rework DEVEX costs and time. For some developers, this also led to higher CAPEX and OPEX estimates as they had to select more advanced or integrate additional process units as part of their system design.

The ability to repurpose existing infrastructure may offer significant cost, schedule and environmental benefits. However, it does come with uncertainty and may not offer full optionality to T&S network users. Examples of this occurred with NEP, HyNet Offshore, and SNZI Offshore, who faced the decision as to whether already existing offshore pipelines could be repurposed for CO_2 transportation (see case study box below).

Like many large-scale infrastructure projects being deployed across the UK, securing an electricity grid connection is proving difficult. Long connection timelines have forced project developers to submit grid connection requests early, even when they have not finalised how much capacity they need. For example, individual SNZI Onshore projects have received commercial offers that have grid connections after their targeted CODs. Such projects are continuing to engage with stakeholders to identify opportunities to alleviate this, but these may come at additional project cost.

CASE STUDY

REPURPOSED VS NEW OFFSHORE TRANSPORT PIPELINES TO CO_2 STORE

HyNet Offshore, SNZI Offshore, and NEP faced the decision between repurposing existing oil and gas assets or building new assets. Use of repurposed assets requires early in-depth studies and, most likely, surveys, to understand the cost-benefit and associated risk trade-offs.

NEP discovered that repurposing was trickier than anticipated, leading to unexpected costs due to additional design complexity. They identified challenges with repurposing, such as corrosion risk from carbonic acid when CO_2 is mixed with water. This was one of the factors in their decision to not proceed with this option, and are pursuing a new build approach.

SNZI Offshore undertook in-depth studies as well as an offshore In Line Inspection survey using an intelligent pig on one of the existing pipelines being considered for CO_2 repurposing. The combination of both of these activities confirmed that repurposing was a viable option and no design modifications would be required to the pipeline.

HyNet Offshore also explored the option of repurposing different infrastructure elements. Although they were not able to repurpose all elements of the relevant offshore process and wellhead platforms due to technical complexities, repurposing the offshore wellhead jackets and pipeline was proven to be a viable option. This led the project to develop an offshore pipeline design with an initial capacity of 4.5 MTPA, with the potential to transport up to 10 MTPA when CO_2 is transported in its dense phase. Other offshore pipelines will be replaced for dense phase operation. The expansion in capacity will require HyNet to replace or supplement the repurposed onshore pipelines. The project decided to progress the 4.5 MTPA initial capacity design as an incremental first phase of material capacity as this offered greater value for money (with reference to their needs case) and could be delivered with reduced costs (both pre-FID and in execution) as well as with smaller construction impacts.

Lessons learnt:

- T&S network developers should try and lock down critical system design elements that have a large impact on downstream components (e.g., storage capacity, CO_2 specification, pipeline capacity). Locking these down early will reduce the need for redesign in the future and provide clarity for all dependent components.
- T&S companies should undertake comprehensive market engagement activities to help firm up the project scope relating to which emitters may connect, depending on final government decisions on emitter selection. This will increase system design clarity and limit significant design changes.
- adequate schedule and budget contingencies should be built into the design of offshore CO_2 pipelines, especially for repurposed ones, as in-depth studies and/or surveys are required which may identify unanticipated issues.
- projects requiring grid connections should apply as soon as possible to enter the queue. They should also identify alternatives in case their desired grid connection date does not materialise.

Regulatory challenges and lessons learnt

Because of the nascency of the UK CCS market, its successful development is heavily reliant on a clear and supportive policy and regulatory environment. The Government has made strides in developing new business models and defining CCS and hydrogen strategies. Nevertheless, certain gaps and uncertainties remain. These have impacted early project development and investor confidence for several projects in taking FID, slowing down the buildout of the UK CCS market.

Policy uncertainty

Challenges: A desire for more detail on the Government's CCS and hydrogen strategies was flagged by the IDC Deployment Projects as one of the reasons why certain project elements like blue hydrogen production plants were not progressed as far as initially intended. This is due to uncertainty around the cluster sequencing process and the timelines for transitioning to a mature market.

Uncertainty surrounding the cluster sequencing process, especially the timelines for Track-2 and Track-1 expansion, has impacted the IDC Deployment Projects' FID and COD timelines. Projects are not willing to invest significant DEVEX for the FEED phase until gaining greater certainty regarding the Track-2 timelines, confirmation on the projects being selected for the anchor or build-out phase under Track-2, or in the case of ZCH, receiving clarity on how the Humber scope will be developed (via Track-1 expansion). This prevents developers from progressing their projects towards the detail that is required for FID, regulatory approvals, and financing arrangements. Additionally, due to the delays in the cluster sequencing process, FEED studies have taken longer than initially scheduled, leading to additional costs.

The cluster sequencing approach has also led to challenges by limiting knowledge sharing. Projects steered away from knowledge sharing due to concerns of anti-competitive behaviour while competing in the cluster sequencing process, which began after the launch of the IDC programme. Projects signalled it would have been helpful to discuss specific topics with their peers, especially the experiences of the Track-1 projects, but this has been limited to date.

Despite updates on the hydrogen strategy and the published CCUS Vision, delays to the cluster sequencing process have sent inconsistent signals to investors and diminished confidence. Investors require certainty on the timelines for transitioning to a merchant market to determine whether they feel confident to invest in the UK CCS market.

Finally, several project developers highlighted the need for greater certainty on the UK carbon price being high enough to justify the long-term benefits of decarbonising via carbon capture. Currently, several CCS projects anticipate their levelised cost of abatement could exceed the Government's carbon price forecasts once government business model support expires. These projects may therefore need continued government support if the carbon price follows its forecasted trajectory. In addition, the ETS adds additional cost to UK projects compared to other locations where there is no equivalent carbon pricing link in place. Without some form of Carbon Border Adjustment Mechanism (CBAM), the carbon price does not give sufficient incentive for some emitters to decarbonise via CCS.

Lessons learnt:

- projects need more detail on the UK's long term CCS and hydrogen strategy, specifically on the timelines and upcoming developments to transition to a merchant market, to feel comfortable investing significant capital.
- IDC Deployment Projects would benefit from additional knowledge sharing opportunities, especially between Track-1 and other projects.
- the UK's carbon price, which underpins the business models, must rise faster than currently projected to enable future CCS projects to be self-sustaining without continued government support.

Business model

Challenges: The business models being developed by DESNZ underpin all early CCS projects by providing developers with the revenue security that enables them to progress projects. Any gaps, uncertainties, or misalignments in these business models can negatively impact a project's ability to take FID.

Several critical business models are currently still being developed, hindering the advancement of projects that are reliant on them. These include models for Hydrogen T&S and NPT[xliv]. Some projects are not yet able to advance because the business models remain under development (see case study box below). More broadly, the lack of hydrogen T&S business models will have an impact on the UK's ability to meet its 2030 low carbon hydrogen goal.

Concerns on business model clarity extend beyond business models gaps (those that are yet to be developed or finalised). Projects that have not been selected in Track-1 of the cluster sequencing process have limited visibility of which expenses will be fully covered by the CO_2 and hydrogen business model support. The same applied to Track-1 projects when they were first selected. Without this assurance that they can recoup their costs, projects are unwilling to spend at risk, putting the UK's 2030 goals at risk. This is particularly impactful for long lead, high capital spend items (e.g., proprietary technology or compressors), which if delayed could impact the project schedule.

The current construct of business models means emitters are required to take full construction, operational and energy risks. Additionally, the Government's requirement for cross-default[xlv] between any capital grants and the 15-year business model for Track-1 projects impose significant risk on the operator. This is exacerbated by the Government's limited alignment to the debt market bankability challenges. Ultimately, this risk imbalance across the value chain impacts projects' bankability and overall affordability. As the CCS market develops, the risk profile across the value chain may change and the risk allocation will need to be revisited.

xliv NPT could either be its own business model or integrated into existing business models.

xlv The cross default clause is included in specific loans or bonds, and it specifies that a default event occurring in one case will carry over to another.

CASE STUDY

THE IMPACT OF BUSINESS MODEL UNCERTAINTY ON SWIC

Emitters in South Wales rely on CO_2 shipping to decarbonise via CCS as there are no local geological CO_2 stores. SWIC has used IDC funding to build an evidence base for CO_2 shipping and advance elements like ship and port design.

DESNZ is currently reviewing the responses to the first call-for-evidence stage of the NPT business model covering CO_2 shipping, which is slated for finalisation in the early 2030s. Until the draft business models are prepared, there is high uncertainty on the FID timelines for the SWIC value chain.

SWIC's uncertainty is exacerbated by the lack of a hydrogen transport business model, as the project's planned hydrogen pipeline cannot proceed until this business model is fully developed. The lack of a clear national network buildout plan beyond the local area has also caused SWIC to pause development on its blue hydrogen production facility[xlvi]. This facility and potential future expansions would contribute towards the UK's ambitious low carbon hydrogen goal, so the delay has a negative impact on achieving the UK's 2030 goals.

Lessons learnt:

- projects will not progress to FID or sometimes even FEED phase until they have clarity on the business models that will be available to them, including which parts of their expenses they will be able to recoup.
- as the CCS market develops, the risk profile across the value chain may change, and the risk allocation in the business models will need to be revisited.

Procurement challenges and lessons learnt

Constructing the IDC Deployment Projects requires billions of pounds in spending on services, labour, and materials. The scale of the procurement required to construct these large-scale infrastructure projects makes this an immense task for projects, especially as they contend with a constrained supply chain and competition from global low carbon projects. Many IDC Deployment Projects raised concerns about securing the resources needed to deliver their projects and noted supply chain challenges risk increasing their project costs and extending project timelines.

Supply chain

Challenges: The UK supply chain is constrained, as the UK has not recently seen infrastructure projects of this scale and complexity. While IDC Deployment Projects are striving to utilise UK content where possible, they acknowledge this will not always be feasible. IDC Deployment Projects are exploring strategies like modular import strategies to import material or outsource

[xlvi] This project is not currently being pursued as an active project.

services from beyond the UK to meet their project needs and timelines. This, however, introduces logistical challenges such as transporting modules to the UK from abroad.

IDC Deployment Projects also raised concerns with sourcing specific equipment. For example, sourcing high-pressure CO_2 compressors has been challenging due to a limited number of vendors globally providing the relevant proprietary or specific technology required. Further, long lead times for many of these proprietary technologies can lead to delays in project delivery timelines and uncertainty about meeting COD timelines. This issue is compounded by the high demand for these items across similar projects nationally and globally and a constrained supply chain.

As project delivery timeframes overlap in a desire to get infrastructure up-and-running by 2030, IDC Deployment Projects expect further disruptions in securing the resources they need to construct these large-scale infrastructure projects. Some projects have already experienced significant delays from vendors due to them overextending themselves across multiple projects.

Lessons learnt:

- projects require greater clarity on local content expectations or goals, as these need to be incorporated early when developing the contracting strategy or conducting market engagement.
- many projects would benefit from a mechanism that allows projects to lock in procurement of critical equipment and materials (i.e., long lead items) ahead of FID. These long lead items might include securing power availability, vessels, and manufacturing capacity. Procuring them pre-FID would reduce the risk of delays to their project schedule.
- the supply chain requires greater visibility of the timing of labour and material resources across the upcoming project timeline, to help them scale operations accordingly. Greater visibility is even more important if future projects have to meet UK or local content goals and are therefore even more reliant on a well-functioning UK supply chain with sufficient capacity.
- developing a workforce plan early and investigating the bottlenecks in supply chain availability is beneficial for planning for supply chain constraints. This exercise helped HyNet Onshore identify that pipefitters, welders, scaffolders, and technicians are the occupations at highest risk of shortages. As a result, they are working with the Engineering Construction Industry Training Board to develop a 'North West Skills Hub' to develop apprenticeships and training programmes concentrated on these occupations.

Tendering

Challenges: The competition for resources detailed in the supply chain subsection above means it is important to provide reasonable procurement conditions that contractors can accept. The constrained supply chain means priority is given to scopes and timetables that are firm. This has been difficult for developers to give due to delays experienced during the cluster sequencing process. This has resulted in contractors declining bids or their bids expiring after their validity period ends.

Projects have also experienced issues with contractors. For example, some projects cited a discrepancy between the knowledge claimed by engineering contractors and their actual capabilities related to these first-of-a-kind projects. Others noted their projects' FEED scopes were not appropriately defined in earlier design phases because the contractors primarily had experience with projects in other geographies, rather than in the UK. This resulted in a lack of understanding of the UK-specific context. On the flip side, project developers have occasionally poorly communicated expectations or scope for contractors since they are also not used to these first-of-a-kind projects. The case study box below highlights the approaches taken by several projects to optimise their contractor selection.

Another challenge raised relates to the public procurement process required as part of cluster sequencing. IDC Deployment Projects noted that this process does not support innovative contracting models like alliances or risk-reward mechanisms. The length of the approval processes has also created challenges. As the Government's assurance and approval process for EPC tenders takes approximately seven months, the IDC Deployment Projects have had to ask for a year's bid validity from EPC contractors. This is not standard practice and often unacceptable to contractors, especially when asking for fixed price bids due to the risk of cost escalations. Projects have used novel approaches to overcome this and other contracting hurdles.

CASE STUDY

A TOOLBOX OF APPROACHES FOR CONTRACTING

The IDC Deployment Projects have taken several approaches to optimise their contractor selection.

NZT Onshore and NEP ran a dual-FEED process between two consortia. This involved inviting contractors from different parts of the value chain to form consortia to bid on the FEED contracts for the power, carbon capture, and onshore compression elements of the projects. The two selected consortia then undertook parallel FEED engineering, designed to encourage competition between them, drive innovation and local content, and deliver the best value for money for their technology selection, with the winning consortium delivering the EPC contract.

As part of ZCH at H2H Saltend, Equinor implemented a pre-FEED design competition, running three parallel pre-FEED studies to get the best overall value and technical solution. They justified the additional upfront costs to better understand each of the three contractors' technical capability, technology solution, and implementation experience. Based on this, H2H Saltend chose one contractor as the project's delivery partner for the FEED, EPC, and O&M phases. Equinor minimised exposure to increased EPC costs when tendering their EPC contract by including a high degree of fixed fee contracts, applying standard inflation indexations when awarding subcontracts, and assigning responsibility for material quantity to the contractor. However, note that without certainty of expected delivery dates, Equinor anticipates it will be difficult to realise the benefits of the approach taken and the contract will most likely have to be renegotiated once clarity on CO_2 T&S access is confirmed.

Lessons learnt:

- projects must scrutinise contractor proposals during the procurement of engineering or construction services to validate their knowledge and experience, particularly with regards to the UK context. Although given the first-of-a-kind nature of these projects, there are limited contractors with experience on similar projects.
- contractors prioritise projects with more certainty, therefore, projects should go to market with the firmest scope and schedule possible.
- running parallel early design stage contracts and choosing the best-performing contractor(s) for delivering future phases can minimise overall contracting costs and risk, despite the higher upfront payments for the first stage.
- projects looking to take FID should accommodate both contractor risk appetite and government approval processes when requesting EPC bids. This can be done by following a bid process in which the contractor can re-validate cost estimates and in which supply chain inflation is accounted for.

Permitting challenges and lessons learnt

Permitting and securing required approvals are critical for a project to progress towards FID. Planning and permitting applications sit on a project's critical path, so any delays hold up the overall delivery timeline. Navigating permitting was a challenge reported by all IDC Deployment Projects. Regulatory authority resource constraints, knowledge gaps on CCS projects, and evolving regulatory standards all contributed to longer approval timelines than projects had initially planned for. Many projects also faced difficulties with coordinating permits across multiple approval authorities.

Process

Challenges: IDC Deployment Projects noted that permitting has been a bottleneck with regulatory reviews, approvals, and determinations taking significantly longer than expected. This can be partly attributed to regulatory bodies reviewing applications for first-of-a-kind projects that involve new technologies, meaning they are learning as they go, and that these applications often necessitate more lengthy and detailed reviews. The DCO process was regarded as particularly complex (see case study box below), although this sentiment extended to other regulatory approvals as well. While IDC Deployment Projects appreciate that regulatory authorities are learning as they go, the long review times create uncertainty for project delivery timelines.

IDC Deployment Projects also indicated the complexity of the current permitting processes, including challenges with the inconsistencies of procedures across England, Wales, and Scotland. For example, SNZI Onshore noted the absence of the DCO process in Scotland, which means planning applications must be submitted to each local authority and can result in different approval outcomes and conditions for the same project[xlvii]. This can increase the timeframe for an already lengthy approval process. Similar

xlvii The impact can be minimised if the planning applications are called in by the Scottish Ministers, but this is at their discretion and is not guaranteed.

inconsistencies were noted by HyNet Onshore, who used a wide range of specialist consultants to support them with navigating the complexities of their permitting applications across England and Wales.

Alongside the complexity of the permitting processes, IDC Deployment Projects noted the high level of effort required to conduct permitting activities. This, they noted, is exacerbated by the number of different regulators and approval authorities they need to engage with to complete permitting and consenting activities for their projects. For instance, the different project elements that were part of the SNZI Onshore and Offshore scopes will require multiple permits to be submitted to and approved by a number of local, regional and national bodies. All of these applications require extensive document preparation, data gathering, often surveys over extended periods and analysis.

Lastly, the inflexibility of the permitting process, especially the DCO process, was raised as a key challenge for the IDC Deployment Projects. This inflexibility, largely on scope, has meant early decisions are required on system architecture to allow the consenting process to progress. Additionally, the inflexibility of the current DCO process makes it hard for projects to make scope changes after submission of their DCO application. Making changes risks incurring significant delays, including potentially having to restart the entire DCO process. Projects are consequently unable, for example, to accommodate new emitters or additional spur pipelines that have emerged since initial submission within the project scope as changes are likely to lead to rework and extended project timelines.

CASE STUDY

THE COMPLEXITY OF DCO

IDC Deployment projects have faced difficulties with the complexity of the DCO process.

NZT Onshore flagged that a greater level of technical detail was required from the FEED contractor to support the DCO application than is typical. This is because parts of the system design that would normally be delivered during the detailed engineering phases was needed to support the DCO application and examination. This led to an increase in the FEED phase costs and timescales.

NZT Onshore and HyNet Onshore noted early decisions were required when defining the system configuration for their onshore CO_2 network to feed into the DCO examination process, which required a degree of certainty.

On ZCH, an original project partner (National Grid Ventures) who was developing the onshore CO_2 and H_2 pipelines departed from the project having completed a round of public consultation on the pipeline route. The development of this pipeline has now been picked up by NEP (bp, Equinor, and Total Energies) who have already held public consultations on a slightly amended route.

Lessons learnt:

- projects should build appropriate contingencies into schedules for long determination timelines during the permitting process.
- projects should prepare detailed permitting and consenting strategies. The strategies should incorporate any specific consenting requirements of relevant local authorities, national bodies or UK nations.
- projects should carefully plan resourcing for permitting and consenting as it often took IDC Deployment Projects more effort than anticipated.
- engaging specialist support on permitting (legal and planning, land, ecology, engagement, environmental) is helpful to navigate the complexities of the process, prepare DCO applications, and progress them through the pre-examination, examination, and subsequent permitting phases.
- selecting emitters for the cluster sequencing process in parallel to the DCO process can be challenging, as they both require degrees of certainty.

Knowledge and resource gap

Challenges: Most regulatory bodies are resource constrained increasing review timelines, especially given the current large quantity of submitted CCS and other energy transition related projects applications. Without steps to close this resource gap through additional staff or process improvements, the backlog is only expected to grow. A growing backlog will cause continued delays to reviews, approvals, and determinations for projects and impact project delivery timelines.

In addition to resource constraints, regulatory bodies are still building their CCS competencies and knowledge. As this is the first wave of CCS projects, regulatory bodies need time to upskill their teams and get familiar with the technology. This is particularly challenging as CCS legislation and regulatory processes are being developed in tandem with the project deployments.

This has sometimes led to inconsistencies and frustrations in the permitting process. For instance, some capture projects had to disclose proprietary capture technology information while others did not. Another example is an HZ sub-project having to adhere to stricter noise requirements than the existing plant for retrofit elements of their project design as well as new-build pieces.

Lessons learnt:

- projects should continue working closely with regulators through regular touchpoints throughout the approval process, helping them understand the project scope and nuances. Open communication and collaboration can support the upskilling of regulatory bodies who are reviewing CCS projects for the first time and currently have both knowledge and resourcing gaps that hinder timely permitting approvals.

Execution challenges and lessons learnt

IDC Deployment Projects are highly integrated, with components of the value chain interdependent. While the IDC programme was effective in bringing industrial cluster stakeholders together towards the common goal of developing first-of-a-kind low carbon projects, IDC Deployment Projects noted the complexity of delivering at a sub-project level and coordinating infrastructure development across the full CCS value chain.

Collaboration and coordination

Challenges: Given the interdependencies between players across the value chain, IDC Deployment Projects need to take an integrated FID to progress to construction. IDC Deployment Projects sometimes found it challenging to optimally coordinate across sub-projects. This was primarily driven by the fact that sub-projects are different and consequently do not have a common delivery timeline. This was further complicated by the number of moving parts, work packages, permitting applications, and business model discussions with the Government. Therefore, projects were often at different stages of development, impacting their ability to progress towards an integrated FID. This also impacted CO_2 network planning, which requires clarity on when and how sizeable emissions from different emitters will flow through the network to support their system design needs.

When trying to integrate several elements to form a complete value chain, forming joint ventures and executing Project Development Agreements are key. Many projects found identifying and agreeing to partnerships time consuming, particularly negotiating joint venture arrangements. Given the first-of-a-kind nature of projects differed from their core business activities, developers struggled to agree the right risk profile across the value chain. This led to protracted negotiations on Joint Venture heads of terms, and significant legal costs.

Once partnerships were formed, some projects found it challenging to keep all partners engaged and incentivised throughout the delivery lifecycle. Given the range of developers within IDC Deployment Projects, each with different resource availability and short-term priorities, their focus and ability to support shifted across development phases. For example, this was a challenge that SWIC faced in the early stages of project development (see case study box below).

Finally, the full effect of collaboration from the IDC programme was limited as a subsequent government process (cluster sequencing) was rolled out with limited industry engagement or awareness. This resulted in two programmes for the development of first-of-a-kind low carbon projects overlapping. The competitive nature of the cluster sequencing process created both legal and perceived barriers to collaboration across clusters, limiting the IDC's goal. This led to many projects having to navigate challenges that were likely faced and overcome by other clusters at a similar or more advanced stage of development. It also resulted in a loss of synergies that could have reduced the overall costs of developing the CCS market. An example of this is each project individually developing customised offtake and transportation agreements in the absence of a standardised set of contractual terms. A more lasting consequence of each project taking different approaches is that new market entrants will have less clarity on the process and contractual terms for connecting to a T&S network because of the lack of standardised agreements.

CASE STUDY

THE IMPORTANCE OF DEVELOPING AROUND AN ANCHOR PROJECT

SWIC's initial consortium contained over thirty partners. While the number of companies who wanted to participate was impressive, they offered varying levels of commitment and the large number made coordination time consuming and complex. A recent change in governance approach has resulted in a focus on development around a key anchor project. This has reduced the complexities of the IDC Deployment Project and from here on out, SWIC will follow a more incremental approach when scaling up to slowly engage the wider cluster.

Lessons learnt:

- the IDC programme was effective at bringing stakeholders together towards a common decarbonisation goal and scope for low carbon infrastructure deployment. This is a model that can be duplicated to drive decarbonisation in other settings.
- government-led competitions should be designed and implemented in a manner that does not unduly inhibit collaboration and knowledge sharing. This can be through specific competition terms that incentivise the timely dissemination of knowledge that would benefit CCS and hydrogen market development.
- Some IDC Deployment Projects with multiple developers involved have found benefit in assigning a "Project Coordinator" who coordinates project interactions with government and regulators, particularly as part of the cluster sequencing process.
- T&S developers need to be proactive about keeping emitter projects engaged. Tactics to do this effectively have included leading recurring meetings focused on progressing towards binding network entry agreements. These meetings can also be used to discuss key technical, commercial, and legal aspects of connection as well as other topics that require collaboration.

Project delivery

Challenges: Delivering low carbon projects in the CCS and hydrogen space is new territory, especially in the UK, for most of the companies involved with the IDC Deployment Projects. The lack of similar projects to benchmark against has made estimating costs and delivery timelines for early development phases (feasibility, pre-FEED and FEED) challenging. Many projects used existing core-business activities and similar industries (oil and gas) as a proxy for cost and delivery schedule. However, this approach underestimated the depth of technical scope required, which led to costs being larger than anticipated. Consequently, developers had to seek additional DEVEX internally, or from other funding sources, additional to IDC funding. For example, the CO_2 pipeline FEED in HyNet Onshore required more detail due to the need to resolve new technical challenges associated with CO_2 system. This resulted in a higher FEED costs than anticipated.

Another key project delivery challenge raised was specific to projects that are retrofitting capture technologies to operational sites. These projects have encountered significant challenges in working around outage planning cycles associated with facilities which typically run continuously (unless there is a need for an unplanned outage or turnaround). Physical works and technical studies that require operational downtime need to be scheduled alongside critical maintenance activities. IDC Deployment Projects retrofitting capture technology to their plants face challenges in meeting the limited windows of opportunity to execute critical project activities, without disrupting business-as-usual operations.

Lessons learnt:

- projects that are retrofitting CCS technologies to existing plants must carefully integrate site outage plans into their project delivery schedules. This helps identify bottlenecks and supports the development of mitigation strategies in tandem with core business operations. The Government needs to recognise this as a timeline constraint for time-bound targets.
- projects must add contingency for budgets and delivery timelines, accepting unknown unknowns are likely. As more CCS projects move through to FID and eventually commissioning, these risks and impacts will become better defined and the need for contingency should decline.

From challenges to recommended actions

This section has detailed the shared challenges experienced by the IDC Deployment Projects. Confronting these challenges has yielded lessons learnt that future projects in the UK and further afield can apply to accelerate development. They have also uncovered gaps in business models, sustainable knowledge sharing, regulator resources, connection standards, and several other areas which require action to rectify. These actions are the focus of the recommendations in the next section.

Section 6: Steps required to enable widespread CCS and low carbon hydrogen deployment in the UK

As discussed in **Section 2**, the UK is already laying the foundation for developing sustainable, mature CCS and low carbon hydrogen markets and the IDC has been fundamental to these efforts. The nine IDC Deployment Projects are proof that the UK's approach has been effective, with the first two clusters scheduled to take FIDs in the Autumn of 2024.

However, to continue the successful rollout of CCS and low carbon hydrogen in the UK, additional actions are required to provide potential market players the certainty needed to invest in and to drive the decarbonisation of UK industry.

Based on a wide range of stakeholder interviews and review of IDC Deployment Project documentation, *Enabling net zero: progress on deploying CCS to decarbonise UK industrial clusters* presents four recommendations to push CCS and low carbon hydrogen development forward in the UK. These are to:

1. provide clear and well-communicated market signals to drive the long-term viability and sustainability of the developing CCS and low carbon hydrogen markets.
2. address business model gaps, offer pre-FID investment coverage, and balance risk allocation to drive greater investor and developer certainty for current and future CCS and low carbon hydrogen projects.
3. ensure that permitting is fit for purpose to meet critical delivery timelines and achieve net zero ambitions.
4. support within cluster coordination and collaboration across the value chain to drive the transition to a sustainable CCS market.

Considered together, the recommendations are intended to support the current IDC Deployment Projects and future CCS and low carbon hydrogen projects through their development. They will help unlock CCS and hydrogen markets which support the UK's transition towards net zero, while delivering economic prosperity and environmental stewardship for the next generation.

For each recommendation, a set of sub-recommendations illustrate how progress can be made. Key stakeholders expected to drive and own these sub-recommendations are also identified.

The sub-recommendations are ordered from most urgent to least using four suggested timing ranges for the implementation of each sub-recommendation:

- ASAP: within 1 year
- Short-term: within 1 to 2 years
- Medium-term: within 2 to 4 years
- Long-term: longer than 4 years

The timings are broadly aligned with the UK's ambition of establishing CCS and low carbon hydrogen sectors by 2030. Lead owners assigned to multiple sub-recommendations should review the actions and prioritise them based on their internal priorities, bandwidth, or direction from the Government.

While the IDC programme has officially concluded, it is important that the focus now shifts towards ensuring swift progress is made on delivering these sub-recommendations. IDC continues to advocate for the establishment of a 'Cluster Advocate' body, as outlined in *Enabling net zero: a plan for UK industrial cluster decarbonisation*[8]. In addition to their previously proposed roles, the body would play a pivotal role in overseeing the delivery of the sub-recommendations and actively driving them forward. The body would be responsible for ensuring each sub-recommendation is executed effectively, evaluating progress towards timely completion, and offering support where needed, such as facilitating collaboration. Through this active leadership, the 'Cluster Advocate' body will drive progress and maintain momentum, thereby translating the recommendations and sub-recommendations into concrete outcomes.

RECOMMENDATION 1

Provide clear and well-communicated market signals to drive the long-term viability and sustainability of the developing CCS and low carbon hydrogen markets

Lenders and project developers require certainty on their business case before investing significant amounts of capital into UK CCS projects. Given the nascency of the market, this requires clear, well-communicated signals from the Government on the evolution of the market, from near-term cluster sequencing timelines to long-term carbon pricing policy. Signals are also needed by the UK supply chain to incentivise them to scale up their currently constrained capacity to handle more low carbon infrastructure projects and meet potential future UK content targets.

These clear and well-communicated signals are essential to de-risk projects as they move through the development lifecycle, bolstering the long-term viability of a mature UK CCS market.

The following four sub-recommendations expand on the above to maximise the value of the developing CCS and low carbon hydrogen markets.

Sub-recommendations

1.1: Communicate transparently and more regularly to the market on the timelines and implementation approach of the cluster sequencing process and the long-term strategy on CCS and hydrogen

Delays in announcements from the Government on the cluster sequencing process have impacted IDC Deployment Projects' FID timelines, leaving projects in limbo while they wait for more clarity. To address this, the Government should provide detailed updates, at least quarterly, on the cluster sequencing process for Track-1 expansion and Track-2 to the market. Updates should be communicated to the widest possible set of interested stakeholders, not only projects within the cluster sequencing process. These updates should include information on new developments that could influence the schedule of projects, such as timelines for cluster sequencing. Projects would appreciate this greater transparency from the Government.

The Government published its longer-term approach to building self-sustaining CCS and low carbon hydrogen sectors in its CCUS Vision and UK Hydrogen Strategy documents, respectively. The documents should also be revised annually. These revisions need not be wholesale. Rather, they should update the market on more detailed implementation and market development strategies that have changed or crystalised since the last update. These currently lack detail in several areas. The frequency of revisions can be adjusted based on industry feedback and the pace at which the market is developed. Updates should also include clear asks for what the Government needs from the market to expedite progress and achieve targets.

The increased communication and transparency will provide more confidence to developers, investors, and the extended supply chain, allowing them to progress and accelerate project development and deployment.

Owner	Timing
Department for Energy Security and Net Zero (DESNZ)	ASAP: To provide clear and regular updates to current and prospective CCS and hydrogen project developers, and market participants.

1.2: Publish finalised business model terms from Track-1 process

Project developers are looking for greater transparency on commercial elements of the Government's business models, such as internal rate of return (IRR), operational performance guarantee conditions, and which parts of project DEVEX and CAPEX will be recoverable. To address this, the Government should provide more transparency on the final negotiated positions of the business models with the Track-1 projects. This can be done through a market update process that includes:

- detail on terms that are open for negotiation on future projects to ensure consistency and fairness with the Track-1 projects,
- ranges on commercial parameters to ensure developers can evaluate their projects and update the scope or design as needed, and
- clarity on the costs covered under the business model such as DEVEX and CAPEX.

Sharing information, where confidentiality of signed contracts permits, will ensure non-Track-1 projects have a level playing field for greater visibility on the commercial envelope. This could drive a more efficient and quicker negotiation process in future stages of the cluster sequencing process.

Owner	Timing
DESNZ	ASAP: To aid Track-1 Expansion and Track-2 projects progressing to negotiations.

1.3: Strengthen visibility into the national and regional pipeline of projects to UK supply chains to encourage them to ramp-up and meet upcoming demand

The UK's supply chain is constrained and unprepared to handle this many new infrastructure projects of such scale and complexity. To address this, the Government should continue to encourage projects to conduct supply chain engagement to raise the profile of the CCS and hydrogen industry in the UK and encourage industry scale up in line with anticipated needs.

Additionally, the Government should develop a single forecast that aggregates all low carbon projects at national and regional levels, including their estimated supply chain needs. The forecast would provide information to supply chains, profiled over time, on the likely services, labour, and material requirements to deliver the pipeline of projects. Given their visibility across the project pipeline, DESNZ are well-placed to produce an aggregated forecast. Where regional and cluster bodies have relevant supply chain information available, they should support DESNZ in producing the national forecast by providing this information. The Government should also consult with the supply chain on how often the forecast should be updated with new information to ensure it is useful for industry.

Understanding the aggregated pipeline across regions would provide the supply chain with greater confidence in the need for their services, although this need ultimately cannot be confirmed until projects take a positive FID or receive a limited notice to proceed. The sooner the visibility of the aggregated project pipeline is provided, the quicker supply chains can evaluate the requirements and ramp up services accordingly to meet likely upcoming demand, provided that they are given the necessary support to do so.

Owner	Timing
DBT	Short term: To encourage and build supply chain capacity quickly.

1.4: Evaluate how to best implement UK content targets to capitalise on the economic benefit of low carbon projects

Since projects need to incorporate any UK content expectations or targets early in their contracting strategy, the current lack of clarity around these expectations saw IDC Deployment Projects wanting more guidance. Clearer expectations or targets are needed to build on IDC Deployment Projects efforts to maximise UK supply chain involvement. To address this the Government should undertake a study which explores:

- what these targets could look like at national (and regional) levels and what their impact would be, recognising current supply chain limitations and the need to meet near-term decarbonisation goals.
- the impacts of such measures across emissions, skills, and working conditions, as well as economics.
- the incentives needed to provide the necessary confidence to the supply chain to ramp up to deliver such targets.
- whether and how mandatory targets can comply with UK subsidy control rules to ensure they are not anti-competitive and yield value for money for taxpayers.
- what existing or proposed EU content rules, as these may influence the UK approach.

Work, guidance, and tools on UK and local content done by the North Sea Transition Authority (NSTA) could be utilised to inform target design[88]. One option could be for UK content to be a non-price criterion for evaluating future CCS and low carbon hydrogen projects, similar to how it is currently considered during renewable leasing rounds. Alternatively, there could be a mandatory target like those set by some global peers[89]. UK content targets could be applied to various areas like services, labour, or materials. Developers could also pass on the requirements through engineering and procurement contracts. It is important that any targets are clearly defined, for instance, whether a % target counts towards a specific category, across a whole project, or against the project CAPEX spend.

The Government should engage with industry and other key stakeholders to capture qualitative considerations for each option and determine the best overall approach for strong UK CCS and hydrogen sectors. There also needs to be a balance between ambitious content targets and delivering initial projects on time to meet 2030 goals.

Evaluating UK content target implementation options would provide projects with more clarity on UK content expectations. Greater UK content would enable economic advantages (e.g., employment, GVA) for the UK and regions where the content is manufactured, including upskilling, and maintain industrial communities.

Owner	Timing
DBT	Short term: To enable targets to ramp up in a way that positions projects to deliver strong economic benefits to the UK. Acting quickly acknowledges the time that it may take to build up the required manufacturing capacity to meet such targets.

1.5: Adjust carbon pricing policy to create an attractive environment for UK CCS investment, supporting the transition towards a self-sustaining market

Currently, several CCS projects have a levelised cost of abatement (as noted by industry) that exceeds the Government's carbon price forecasts once government business model support expires. This makes the long-term financial sustainability of these projects uncertain. To address this the Government should take measures that deliver steeper UK carbon price growth than currently forecast. For example, they could align the UK's ETS with the EU's to prevent the UK's carbon price from further diverging from more bullish EU forecasts. Carbon pricing should not be too aggressive, as excessive carbon costs may cause companies to offshore activities or go out of business.

To help prevent this, the Government should develop a UK CBAM in a similar timeframe to the EU's to ensure the long-term viability of CCS projects as the UK moves towards a non-subsidy-based environment. This will make sure UK industry is not undercut by cheaper high carbon goods from abroad by adequately pricing in the carbon emissions and strengthening the competitive position of the UK industry. It would also encourage UK-based manufacturers to produce low carbon equipment and materials, bolstering the impact of sub-recommendation 1.4.

These carbon pricing measures would provide projects with greater certainty that the UK carbon price will be high enough to justify decarbonising via carbon capture. This aligns with the Government's ambition to limit subsidy support in a future mature market, and would increase investor confidence in the UK CCS industry.

Owner	Timing
DESNZ	Short to medium term: To lay the groundwork for strong long-term carbon price signals.

RECOMMENDATION 2

Address business model gaps, offer pre-FID investment coverage, and balance risk allocation to drive greater investor and developer certainty for current and future CCS and low carbon hydrogen projects

Deploying large-scale CCS and low carbon hydrogen projects requires significant amounts of private capital, with worldwide investments in CCS doubling between 2022 and 2023[90]. Established companies like bp have set up low carbon business units and new CCS companies like Storegga have been founded. This shows there is appetite in the market as both developers and investors are looking to grow their project portfolios by investing in the CCS and hydrogen sectors.

However, several IDC Deployment Projects noted that their ability to advance their projects towards FIDs are limited due to incomplete integration of areas critical to supporting first-of-a-kind projects like CO_2 shipping and hydrogen transport into government business models.

Furthermore, the current risk profiles in the business models that have been developed are seen as unbalanced from the perspective of some IDC Deployment Projects. This impacts their ability to access project financing.

The following three sub-recommendations expand on the above to enable the UK to capitalise on the appetite from developers and investors to inject capital towards large scale CCS and low carbon hydrogen projects.

Sub-recommendations

2.1: Develop and finalise business models coverage for hydrogen transport and storage and CO_2 shipping to enable projects that rely on them to advance

Some projects are reliant on CO_2 shipping to make carbon capture a viable decarbonisation option for them. For other projects, the lack of clarity on hydrogen transport business models is holding hydrogen production and transport network development back. To address this, the Government should finalise development of the business models relevant to hydrogen transport and storage and CO_2 shipping (and other NPT)[xlviii].

DESNZ can use its experiences of developing the core CCS business models to streamline the development process. Development has already accelerated from four to five years for core capture business models to two years for the Low Carbon Hydrogen Agreement (LCHA).

A form of CO_2 shipping business model [xlviii] is critical for industrial clusters with no proximity to geological storage. Additionally, it would help build a market for CO_2 shipping that allows the UK to leverage its natural advantage of having significant CO_2 storage capacity. This will help lay the groundwork for the UK to be a CO_2 importer, a key goal outlined in the UK's CCUS Vision.

[xlviii] NPT could either be its own business model or integrated into existing business models.

The hydrogen transport and storage business model is a key component to enable the deployment of shared hydrogen infrastructure, enabling wide scale cluster decarbonisation through fuel switching or hydrogen blending. Furthermore, hydrogen pipeline transport will also be a key enabler to ramp-up low carbon hydrogen production as producers won't have to rely on co-location with nearby offtakers.

Owner	Timing
DESNZ	Short term: To finalise hydrogen transport and storage business models. Medium term: to develop NPT business model[xlviii] draft terms before Track-2 FIDs, especially for CO2 shipping.

2.2: Develop a limited notice-to-proceed mechanism to enable projects to secure schedule-critical long lead items ahead of the FID stage gate

Thus far, projects in cluster sequencing have not secured long lead items given their unwillingness to spend CAPEX at risk without a guarantee that spending can be recovered if the Government decides not to proceed with the project. To address this, the Government should develop a limited notice-to-proceed mechanism that offers coverage to advanced projects approaching FID to secure long lead items ahead of their FID stage gate. These advanced projects are those that are selected for business model negotiations through the cluster sequencing process.

CO_2 compressors, pipeline materials, offshore vessels, and grid connections are all examples of long lead items, which could be major critical path bottlenecks if purchase is delayed until after FID, risking project schedules aligned with the UK's 2030 goals. As projects concurrently in development demand many of the same components and are likely to deploy at the same time, this will further constrain the supply chain and exacerbate timeline risks of long lead items. The need for timely securing of long lead items is also exacerbated by other schedule constraints like weather events limiting offshore construction activities or having to time carbon capture equipment installation around plant turnaround cycles.

The Government should work with projects to identify additional expenses including those listed above which, if not taken pre-FID, can significantly extend project timelines. They should then review the cost-benefit (including value for money assessment) of a limited notice-to-proceed. Such a mechanism should balance between enabling projects to advance while minimising risk to the Government.

[xlviii] NPT could either be its own business model or integrated into existing business models.

The limited notice-to-proceed mechanism would enable projects to secure long lead items early and avoid potential schedule delays, maintaining progress towards the UK's 2030 goals. Ultimately, this sub-recommendation aims to optimise the trade-off between efficient Government subsidies and meeting ambitious decarbonisation goals.

Owner	Timing
DESNZ	ASAP: To enable projects to realistically meet UK goals.

2.3: Adjust risk allocation within future iterations of the business models to re-balance in line with increasing market maturity

IDC Deployment Projects have indicated that the current risk allocation of the business models is not balanced in certain areas, potentially hindering future developers from moving forward with higher-risk projects in the still-nascent CCS and low carbon hydrogen market. Business models have so far been designed for first-of-a-kind projects that require government support to be economically viable.

However, the risk model for emitter models requires project developers to take full construction risk, operational risk, and energy price risk over the 15-year contract period. Also, stringent business model conditions may not always account for interactions or interdependences between different models across the full value chain. This encourages projects to try to minimise their risks as much as possible to make sure they meet the eligibility criteria of the cluster sequencing process. This impacts project affordability.

The Government should adjust business models in line with a transition to a self-sustaining market, using information on project risks and operational performance gathered from Track-1 projects, later UK projects, or successful international projects. This approach to risk management will enable the market to move towards a more mature state. As with current business model development, adjustments should be made in close consultation with industry.

Reviewing business models on these grounds will lead to models that better reflect the maturity of the CCS and low carbon hydrogen markets, potentially reducing the level of ongoing subsidy support required from the Government sooner.

Owner	Timing
DESNZ	Continuous: To be done as the market evolves and as operational learnings accrue.

RECOMMENDATION 3

Ensure that permitting is fit for purpose to meet critical delivery timelines and achieve net zero ambitions

Permitting has been a bottleneck for many IDC Deployment Projects. Approvals have in some cases taken over a year longer than expected. Regulators are resource constrained. Processes differ across UK nations and local areas, and they are often inefficient and complex. These issues have extended project timelines across the board.

Planning and permitting processes and the bodies that manage them must be made fit for purpose so that the issues faced by first-of-a-kind projects are ironed out for future waves of CCS deployment.

Processes should be reviewed to identify areas where they can be streamlined or improved. Regulators should build their internal capacity for assessing the increasing influx of CCS and other low carbon projects expected over the next decades. Major permits like the DCO should have more scope flexibility built into them, for instance, to account for changes in emitters connecting to proposed pipelines. Finally, the Government should explore opportunities to harmonise planning processes across UK nations.

The following four sub-recommendations expand on the above to accelerate project planning and permitting for the CCS sector, but also for wider low carbon development. While these sub-recommendations require action from the Government and regulatory bodies, the private sector and project developers must respect regulators' time, submit high quality applications, and be good stewards of the project development process.

Sub-recommendations

3.1: Revamp the permitting and planning statutory process to simplify, improve or streamline it for future low carbon infrastructure projects

Deployment Projects indicated that complex, inefficient, and slow permitting processes are a hold up in project delivery. To address this, the Government should review current permitting and planning processes to identify how they can be streamlined. This action requires first determining the body responsible for national permitting and planning statutory reviews.

Opportunities to streamline could include revising the process to fast track nationally significant infrastructure projects, allowing the submission of an integrated application to progress across all departments for all projects, looking at different ways to process similar applications, tightening pre-screening processes, or batching applications together. These efforts can build on the previous government's Nationally Significant Infrastructure Project (NSIP) Action Plan[91], which set out how they would reform the consenting process to ensure the planning system can meet the demands of a greater number and complexity of cases.

One element of the DCO process that IDC Deployment Projects appreciated was the statutory timeline for examination stages[xlix]; this could be worth replicating across other permitting and approval processes, where possible.

Simplifying and updating the process would accelerate delivery for current CCS projects in development or the next wave of projects. It would also assist wider energy transition projects across the power and hydrogen sectors.

Owner	Timing
DESNZ, Scottish Energy and Climate Change Directorate, Welsh Economy Energy and Transport Group	ASAP: To ease this consistently cited bottleneck in project development timelines.

3.2: Continue to build up internal capacity and competencies across the regulatory bodies to facilitate timely and thorough review of low carbon projects

Regulatory reviews, approvals, and determinations related to permitting and consenting have taken significantly longer than expected for IDC Deployment Projects. As well as the inefficiency of permitting processes discussed in the previous sub-recommendation, these delays are at least in part due to the limited capacity within regulatory bodies to handle the quantity of applications.

To address this, the various regulatory bodies relevant to low carbon project approvals should invest in building up internal capacity, thus better positioning themselves to manage future waves of CCS and low carbon hydrogen applications more quickly. Such efforts should include upskilling of staff in the specifics of low carbon infrastructure projects to facilitate efficient engagement with project developers. There could be a role for academia in delivering this. For instance, the UK Carbon Capture & Storage Research Centre (UKCCSRC) runs regular teach-ins on technical aspects for the Environment Agency (EA) and DESNZ. Knowledge sharing from industry can also drive higher-quality applications which can reduce strain on regulators.

Early visibility into the project pipeline would also help regulators to better understand the number of resources required. This would enable regulatory bodies to adjust their resource profiles or update anticipated processing timelines accordingly. To accomplish this, the Government could develop a tool that provides insights to regulators on the national and regional pipeline of projects. This could be similar to or linked to the forecast of supply chain needs detailed in sub-recommendation 1.3. It would outline where projects are in the development cycle and when they can anticipate applications for permitting and consenting.

Owner	Timing
All national, regional, and local regulatory bodies, including Department for Housing, Communities and Local Government (DHCLG), Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW), Health and Safety Executive (HSE), EA, NSTA and others	Short-term: To prepare for the large number of net zero projects that will be going through the regulatory processes in the coming years.

xlix Note that DCOs in many cases still took significantly longer than projects had scheduled. This was due to the pre-examination period not having a statutory time limit.

3.3: Allow more scoping flexibility within the DCO or equivalent planning processes to better accommodate the evolving requirements of CCS and low carbon hydrogen projects

The current scoping inflexibility of the DCO has meant projects have had to make early decisions on system architecture. It has also made them unable to accommodate new emitters within the design without needing to significantly rework their DCO application. This necessitates additional review, delays project timelines, and increases costs.

To address this, regulatory bodies should allow for greater flexibility for projects during the relevant planning process, such as allowing projects to update their application as the design matures through the development phase. For example, a pipeline application could be further iterated upon as the number of emitters joining the network is confirmed and the emitter flow profile is finalised.

At a minimum, regulatory bodies should work with industry to define a threshold level of scope change that does not necessitate major application rework. This should apply to more locationally granular planning processes such as the Town and Country Planning Act (TCPA) as well as the DCO.

Allowing for more flexibility would ensure projects can deploy an optimised design without adding significant time to the project schedule, particularly during this period of nascency for CCS and low carbon hydrogen markets.

Owner	Timing
DHCLG, SEPA, NRW	Short-term: To allow for more scope flexibility as soon as possible.

3.4: Explore opportunities to harmonise the planning processes and requirements across England, Wales, and Scotland to facilitate rollout of cross-border low carbon projects

Projects have indicated challenges with inconsistencies in permitting procedures across the different countries of the UK, creating further complexity during the permitting process. To address this, the Government should explore opportunities to harmonise these planning processes and requirements across the UK.

Doing so would first require a comparison of planning processes and requirements across England (DLUHC), Wales (NRW), and Scotland (SEPA) to identify areas where alignment would be beneficial. A body should be identified as responsible for enacting recommended areas of best practice alignment. This could be an existing body, or a newly created one.

Harmonising would simplify permitting procedures for developers of large infrastructure projects, especially for cross-border projects.

Owner	Timing
DESNZ	Medium to long-term: To take the time needed to navigate the complexities of devolution to UK nations. Also, this sub-recommendation is best implemented once sub-recommendations 3.1 and 3.3 have been undertaken.

RECOMMENDATION 4

Support within cluster coordination and collaboration across the value chain to drive the transition to a sustainable CCS market

While the IDC programme was effective in bringing industrial cluster stakeholders together towards the common goal of developing first-of-a-kind projects, IDC Deployment Projects noted the complexity of coordinating across the full CCS value chain. Several IDC Deployment Projects and industrial clusters found it challenging to coordinate individual sub-projects at different stages of development due to the number of moving parts. Robust cluster orchestration is needed to navigate these complexities.

Coordination challenges were exacerbated as most companies engaged in the IDC Deployment Projects were new to the CCS space. They faced similar difficulties in developing first-of-a-kind projects in areas such as technology selection, navigating the Government's cluster sequencing process, or understanding the relationships between CO_2 capture rates and transport and storage flows. Being able to collaborate more closely and take on board lessons learnt from early projects can streamline project development for ongoing and future projects.

The following three sub-recommendations expand on the above to support project and market coordination that can drive the development of a strong and world-leading UK CCS sector.

4.1: Establish a publicly run knowledge sharing hub where CCS market participants can share lessons learnt and collaborate on CCS market development

IDC Deployment Projects steered away from certain knowledge sharing activities due to concerns of anti-competitive behaviour while competing in the cluster sequencing process. They signalled that they would benefit from a more open environment for discussions with their peers. To address this, the Government should establish a publicly run CCS and low carbon hydrogen knowledge-sharing hub, which would provide an outlet for projects to share learnings across technical, regulatory, commissioning, and operational topics, amongst others through regular forums and other events. It can also act as a central online repository for publicly available project documentation.

Since DESNZ has visibility of all projects applying for the cluster sequencing process, it is well placed to set up such a hub, run directly or by a third-party publicly funded body. DESNZ could advise on the appropriate information that projects could legally share without breaching cluster sequencing confidentiality. There is international precedent for projects receiving Government funds to abide by strict knowledge sharing requirements. For example, Norway's Longship project is mandated to transparently share knowledge as the Norwegian Government is underwriting a majority of the development costs[92]. DESNZ could apply similar requirements to projects benefiting from government business models, obliging participation in the hub and meaningful contributions to knowledge sharing events and the document repository. Clear terms of commitment and reference would prevent such a hub from becoming an industry marketing mouthpiece.

Such a hub would offer ongoing and future projects the information and contacts needed to hit the ground running, enabling them to accelerate their project development, bypass issues that previous projects have faced, and focus on innovation to drive down costs. The hub should be developed with a culture of sharing knowledge and signposting new entrants to people with relevant project experience.

Owner	Timing
DESNZ	ASAP: To be able to provide knowledge from Track-1 to ongoing projects.

4.2: Define a best practice model for intra- and inter-cluster orchestration that ensures strong leadership, collaboration along the value chain, and knowledge sharing practices

IDC Deployment Projects noted how complex it was to align the various projects along the value chain at the cluster level. This included sequencing work packages across the cluster, coordinating planning and permitting across multiple projects at different stages of development, progressing an integrated FID, and engaging with the Government on the financial business case. To address this, the Government should identify a best-practice model for cluster orchestration that can be a blueprint for future CCS and low carbon hydrogen projects in the UK and beyond.

The model can be developed using learnings from the IDC Deployment Projects, the framework developed in the *Enabling net zero: a plan for UK industrial cluster decarbonisation* report, and from other industry associations. It should include recommended approaches for cluster set up and governance, knowledge sharing, and cross-company collaboration.

Establishing this model now gives current and future projects a template to use for building better alignment across the multitude of relevant stakeholders.

Owner	Timing
DESNZ	Short-term: To quickly improve cluster orchestration for ongoing and future clusters and showcase UK leadership.

4.3: Develop a standardised approach and template for creating offtake and transportation agreements

Each CCS project is individually developing customised offtake and transportation agreements with producers and users. This is a time-consuming and expensive undertaking. To address this, a publicly led working group should develop a standardised approach to these agreements based on learnings from prior agreements. Representatives from T&S Companies and emitters should be included in the working group.

The standard approach could include creating a template agreement which can be adjusted as needed for specific nuances, such as variable CO_2 flows from abated gas power plants. It could also include developing templates for non-binding arrangements with different parties.

Ultimately, such standards will support CCS market expansion by providing clarity to new entrants on the process and standard terms of connecting to a T&S network.

Owner	Timing
DESNZ, T&S Companies, and project developers	Medium-term: To enable the market to evolve naturally via bilateral discussions between emitters and T&S Companies.

Summary of recommendations

TThe below table briefly summarises all four recommendations and corresponding sub-recommendations. The table includes the proposed lead organisation(s) and any supporting actors for each sub-recommendation, as well as the relative urgency of their implementation.

Table 2: Summary of recommendations and corresponding sub-recommendations

#	Recommendations to support the CSS sector	Lead	Supporting Actors	Urgency[I]
1	**Provide clear and well-communicated market signals to drive the long-term viability and sustainability of the developing CCS and low carbon hydrogen markets**			
1.1	Communicate transparently and more regularly to the market on the timelines and implementation approach of the cluster sequencing process and the long-term strategy on CCS and hydrogen	DESNZ	Project developers	ASAP
1.2	Publish finalised business model terms from Track-1 process	DESNZ	Industry, Investors, Project developers	ASAP
1.3	Strengthen visibility into the national and regional pipeline of projects to UK supply chains to encourage them to ramp-up and meet upcoming demand	DBT	Project developers, Industry	Short term
1.4	Evaluate how to best implement UK content targets to capitalise on the economic benefit of low carbon projects	DBT	DESNZ, His Majesty's Treasury (HMT), Industry	Short term
1.5	Adjust carbon pricing policy to create an attractive environment for UK CCS investment, supporting the transition towards a self-sustaining market	DESNZ	HMT, European Commission	Medium term
2	**Address business model gaps, offer pre-FID investment coverage, and balance risk allocation to drive greater investor and developer certainty for current and future CCS and low carbon hydrogen projects**			
2.1	Develop and finalise business models coverage for hydrogen transport and storage and CO2 shipping to enable projects that rely on them to advance	DESNZ	Project developers, Ofgem	Short term (H_2 T&S) Medium term (NPT)
2.2	Develop a limited notice-to-proceed mechanism to enable projects to secure schedule-critical long lead items ahead of the FID stage gate	DESNZ	Project developers	ASAP
2.3	Adjust risk allocation within future iterations of the business models to re-balance in line with increasing market maturity	DESNZ	Project developers, Technology providers, Project lenders	Continuous

I Suggested implementation timings are as follows: ASAP: within 1 year; short-term: within 1-2 years; medium-term: within 2-4 years; long-term: longer than 4 years

Table 2: Summary of recommendations and corresponding sub-recommendations

#	Recommendations to support the CSS sector	Lead	Supporting Actors	Urgency[I]
3	**Ensure that permitting is fit for purpose to meet critical delivery timelines and achieve net zero ambitions**			
3.1	Revamp the permitting and planning statutory process to simplify, improve or streamline it for future low carbon infrastructure projects	DESNZ, Scottish Energy and Climate Change Directorate, Welsh Economy Energy and Transport Group	DHCLG, SEPA, NRW, Project developers, National Infrastructure Commission (NIC)	ASAP
3.2	Continue to build up internal capacity and competencies across the regulatory bodies to facilitate timely and thorough review of low carbon projects	DHCLG, SEPA, NRW, HSE, EA, NSTA, etc.	NIC, Infrastructure and Projects Authority (IPA)	Short term
3.3	Allow more scoping flexibility within the DCO or equivalent planning processes to better accommodate the evolving requirements of CCS and low carbon hydrogen projects	DHCLG, SEPA, NRW	Project developers	Short term
3.4	Explore opportunities to harmonise the planning processes and requirements across England, Wales, and Scotland to facilitate rollout of cross-border low carbon projects	DESNZ	DHCLG, SEPA, NRW	Medium to Long term
4	**Support within cluster coordination and collaboration across the value chain to drive the transition to a sustainable CCS market**			
4.1	Establish a publicly run knowledge sharing hub where CCS market participants can share lessons learnt and collaborate on CCS market development	DESNZ	IDC Clusters, IDC Deployment Projects, CCSA	ASAP
4.2	Define a best practice model for intra- and inter-cluster orchestration that ensures strong leadership, collaboration along the value chain, and knowledge sharing practices	DESNZ	IDC Cluster Plan Leads, IDC Deployment Projects	Short term
4.3	Develop a standardised approach and template for creating offtake and transportation agreements	DESNZ, T&S Companies, Project Developers	N/A	Medium term

I Suggested implementation timings are as follows: ASAP: within 1 year; short-term: within 1-2 years; medium-term: within 2-4 years; long-term: longer than 4 years

Conclusion

The IDC Deployment Projects are a crucial component of realising industrial decarbonisation in the UK. The last five years of project development supported by IDC funding has yielded clear progress. The UK is ever closer to achieving its targets around carbon capture, hydrogen production, and low carbon cluster formation.

Still, the path ahead is long, and continued progress is not a foregone conclusion. The UK must remain focussed on, and dedicated to, supporting industrial decarbonisation if it is to secure the transition to net zero by 2050.

Between outstanding decisions around the financing and regulation of CSS, as well as the ongoing need for coordination between key stakeholders, close collaboration is needed across government, industry, and other players within the CCS market to maintain momentum on industrial decarbonisation.

This report has synthesised the challenges faced, and lessons learnt by IDC Deployment Projects, highlighting opportunities for future projects to develop more efficiently. The resulting recommendations chart a path for CCS to play a decisive role in the UK's journey to net zero, enabling the UK to decarbonise rather than deindustrialise.

Appendix 1: IDC Deployment Projects overviews

HyNet Onshore

Overview:

HyNet Onshore is located in the North West England and North Wales. The overall programme integration is led by Progressive Energy. The IDC Deployment Project key scope includes the following elements[40]:

- **Industrial carbon capture:** Carbon capture plant installed on Essar Energy Transition's (EET) fluid catalytic cracker at Stanlow Manufacturing Complex.
- **Industrial carbon capture:** Carbon capture facility installed on Heidelberg Materials' Padeswood cement plant.
- **CO_2 transport**: New build onshore CO_2 pipeline developed by Eni.
- **H_2 transport:** New build onshore hydrogen pipeline developed by Cadent.
- **H_2 storage:** Hydrogen storage in underground salt caverns managed by Inovyn.

The IDC Deployment Project's (EET and Heidelberg Materials facilities) total carbon capture capacity is up to 1.7 MTPA[36,37]. The captured CO_2 will connect to the onshore CO_2 transport network, which has a capacity of 4.5 MTPA[43]. The onshore hydrogen transport capacity is between 4.25 to 6.75 GW, dependent on the operating pressure[37].

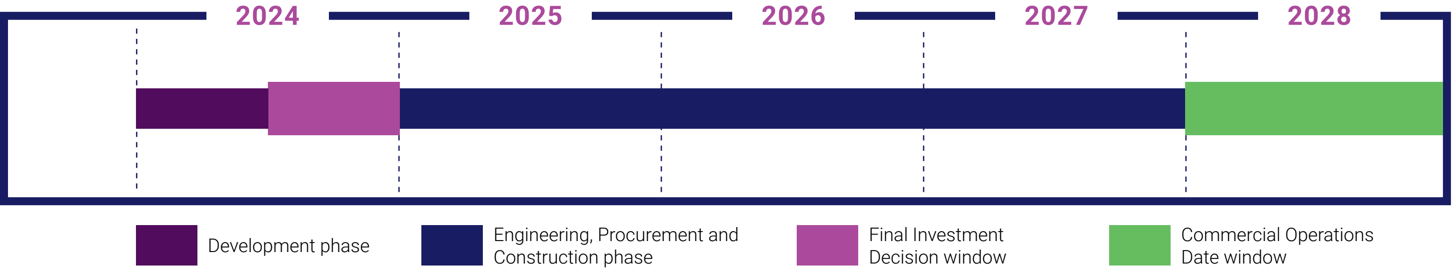
The onshore CO_2 transport infrastructure will support CO_2 flows from the broader HyNet cluster beyond the initial anchor sources, including emitters selected through the Track-1 expansion process. This availability of shared infrastructure will enable future carbon capture and hydrogen production projects to come online.

Business model support:

The HyNet Onshore project will seek financial support from the following government business models: T&S Regulatory Investment (Onshore CO_2 transport), Industrial Carbon Capture (CO_2 capture facilities), Hydrogen Transport and Hydrogen Storage[40].

Infrastructure delivery[40]:

Figure 24: HyNet Onshore indicative project timeline[li]



Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.

Although HyNet features a combined CO_2 and H_2 scope of work, the different natures of these systems and their reliance on different business models necessitated separate development workstreams and schedules[40]. The CO_2 scope, including the first hydrogen production plant, is targeting an earlier final investment decision, integrated with the HyNet Offshore scope, for the Autumn of 2024, with operations starting in 2028[40]. FID for the wider hydrogen network and storage is planned around 2026[40].

Challenges and lessons learnt[85,40]:

- **coordinating project maturity:** As a project with multiple partners, sequencing and aligning work packages was challenging. This included coordinating planning and permitting across multiple projects which were, at times, at different development stages. Cooperation between industry and government to develop a viable project strategy helped mitigate this.
- **workforce limitations in the supply chain:** Although the necessary supply chain skills largely exist in the UK, the constrained market has resulted in competition for the limited resources available. To minimise the effect of this, HyNet undertook comprehensive supply chain engagement and, in some cases, initiated early contractor engagements for construction partners. Additionally, HyNet developed an early-stage workforce plan to identify which skillsets are most at risk of shortages[37].
- **greater engineering detail required:** A greater level of detail was required to support the DCO application because design that would normally be delivered in the detail engineering phases was needed during the FEED phase. This highlights the importance of engaging with engineering contractors to understand the FEED scope of work for a DCO submission.

li HyNet CO_2 FID and COD are shown. HyNet H_2 FID & COD is expected later as the project scope is separated between CO_2 and H_2.

HyNet Offshore

Overview:

HyNet Offshore is led by Eni. The IDC Deployment Project key scope includes the following elements[43]:

- **CO_2 transport and storage:** Repurposed onshore and offshore pipelines, new CCS platform and repurposed wellheads platforms with new CCS topsides to transport and inject CO_2 for permanent storage in the depleted gas fields of Liverpool Bay.

The CO_2 offshore transport and storage capacity for the first phase of the network is 4.5 MTPA[43].

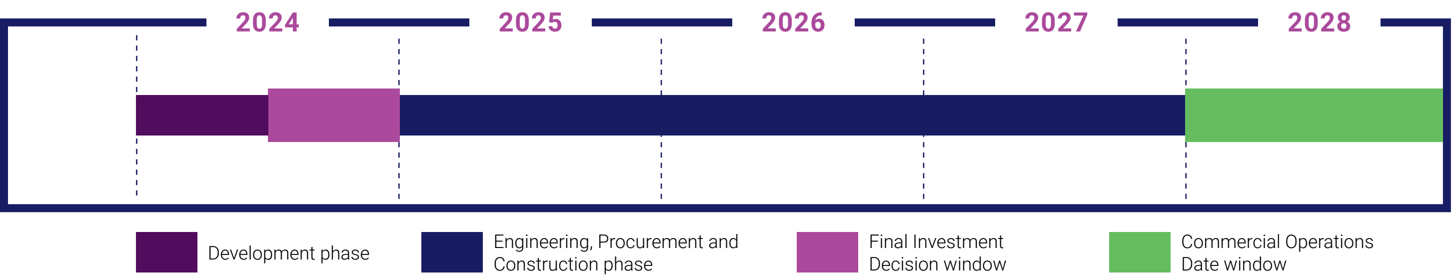
HyNet Offshore completes the HyNet Onshore CO_2 value chain by providing the connecting onshore and offshore transport and storage network. The Deployment Project includes carbon capture projects in North West England and North Wales, including Essar Energy Transition, Protos, Heidelberg Materials and Viridor[40]. The project will deliver the foundational infrastructure that will be utilised by a range of other regional emitters, including the Essar refinery, in the future as they decarbonise their operations.

Business model support:

The HyNet Offshore project will seek financial support from the following government business model: T&S Regulatory Investment (CO_2 transport & storage)[43].

Infrastructure delivery:

Figure 25: HyNet Offshore indicative project timeline[lii]



Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.

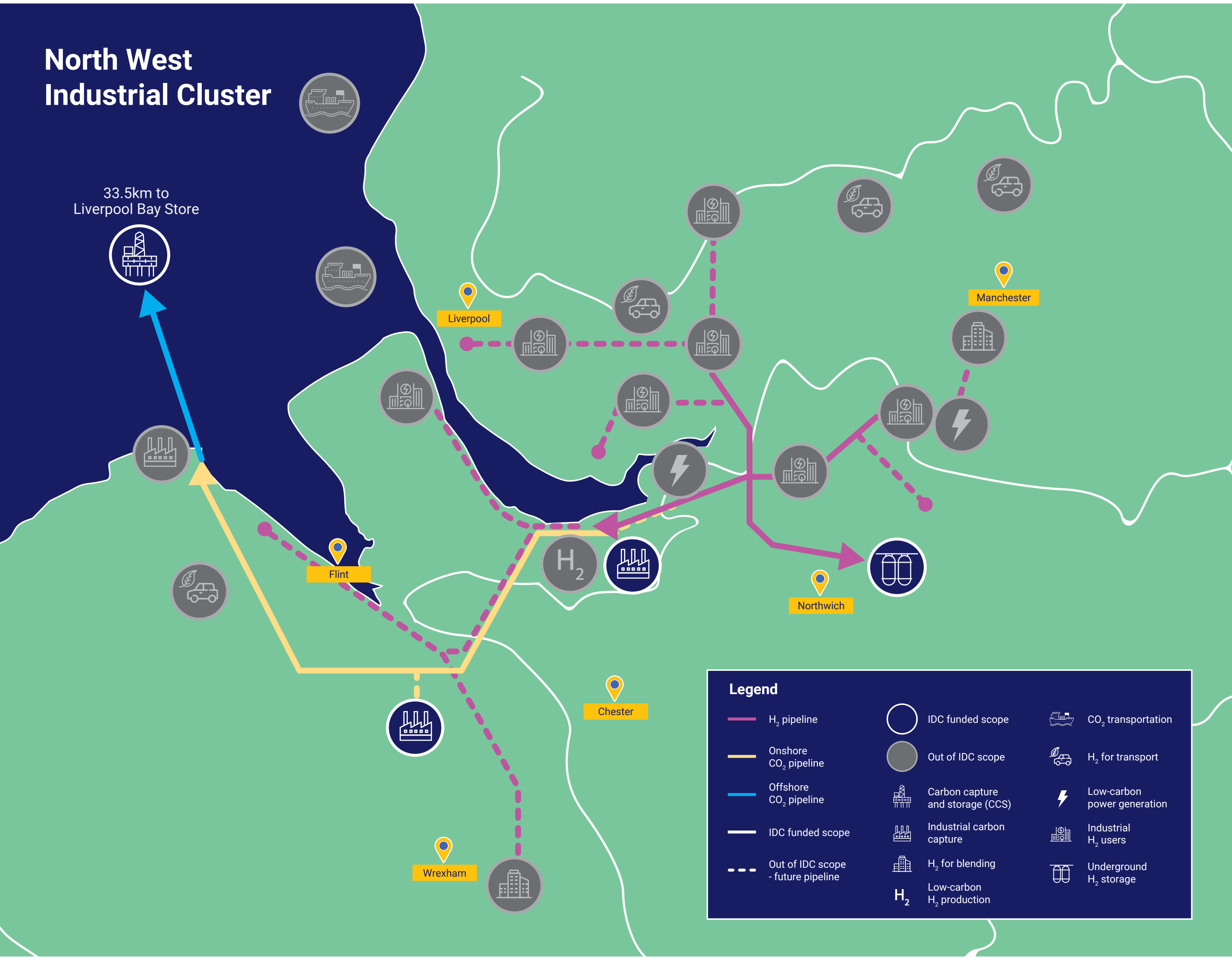
The HyNet Onshore and Offshore scopes are following an integrated approach with similar timeframes as part of a full CO_2 value chain approach. This includes the key milestones such as FID and COD.

[lii] HyNet CO_2 FID and COD are shown.

Challenges and lessons learnt[43,85]:

- **technology repurposing costs:** Repurposing assets such as pipelines or the processing platform is complex and required in-depth studies. The studies identified what could be repurposed and what could be achieved with an acceptable level of schedule risk. Exploring repurposing options has led to cost savings on the project and offered greater value for money.
- **limited collaboration:** Due to the competitive aspect of the cluster sequencing process, the collaboration between the Track-1 clusters was initially limited. Once HyNet and East Coast Cluster were appointed as Track-1 clusters, the projects were able to collaborate further on technical areas of common interest and wider benefit such as CO_2 specifications.

Figure 26: North West industrial cluster overview



Net Zero Teesside Onshore

Overview:

NZT Onshore is situated in Teesside and led by bp. The IDC Deployment Project key scope includes the following elements[93]:

- **Clean power:** Greenfield gas fired power station installed with carbon capture technology.
- **CO_2 transport:** Onshore CO_2 transport network for the Teesside industrial emitters.

The power CCS project has a carbon capture capacity of up to approximately 2 MTPA[46], whereas the onshore transport has a capacity of 10 MTPA[94,95].

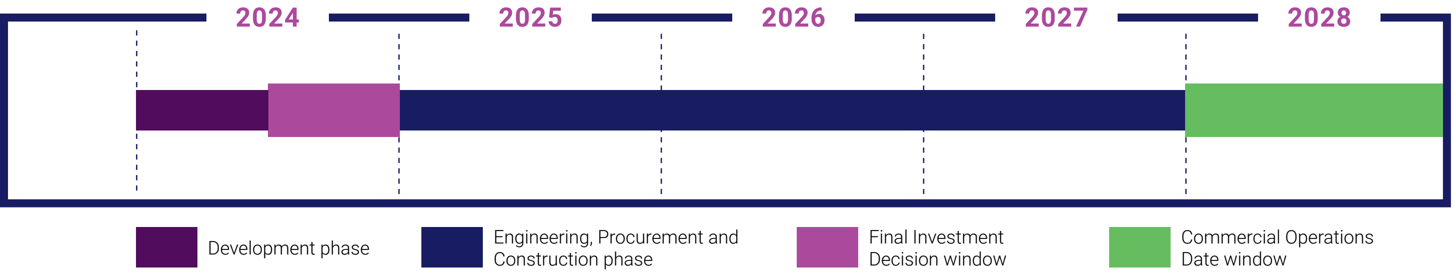
The onshore CO_2 transport network is designed to support cross-sector industrial decarbonisation in the Teesside region. This includes current Track-1 projects such as BOC's Teesside Hydrogen CO_2 Capture, bp's H2Teesside, and NZT Power[26]. Future projects such as the Kellas Midstream H_2NorthEast, NorSea Carbon Capture and many others can also benefit from the shared transport network[96].

Business model support:

NZT Onshore will receive financial support from Dispatchable Power Agreement (Power CCS) and T&S Regulatory Investment (Onshore CO_2 transport)[93].

Infrastructure delivery[46]:

Figure 27: NZT Onshore indicative project timeline



Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.

NZT Onshore received DCO approval in February 2024, which will allow it to proceed for a cluster FID alongside NEP and other Track-1 Teesside projects by the Autumn of 2024[46].

Challenges and lessons learnt[85,93]:

- **revalidation of contractor bids:** The lengthy government approval process as part of the cluster sequencing process meant the project needed to ask EPC contractor bids to be valid for a period of around one year. In order to achieve this, NZT Onshore implemented a re-validation process allowing contractors to provide updated costs within a defined process after around six months.
- **delivering the best design:** The power, capture, and compression scope, which was a first-of-a-kind concept, meant there was additional uncertainty and higher risk associated with the project. To offset this, NZT Onshore ran a dual-FEED process between two consortia designed to promote competition and deliver the best value for money[46].

- **setting up the project joint venture:** Establishing a CCS project in the UK was new to all project partners. This meant setting up the joint venture was more complex as it presented different risk profiles compared to the project partners' core businesses.
- **lengthy permitting process:** The backlog of DCO application consents and outstanding judicial review cases in progress meant receiving DCO took significantly longer than expected (more than 1.5 times the planned timeframe).

The Northern Endurance Partnership

Overview:

NEP is led by bp. The IDC Deployment Project key scope includes the following elements[93]:

- **CO_2 transport and storage:** Infrastructure connecting Teesside and Humber compression and pumping stations to a common manifold and well injection site at Endurance store in the Southern North Sea.

The Teesside and Humber export connection of the new offshore pipelines have capacities of 10 MTPA and 17 MTPA, respectively[53]. The first phase of the project will transport and store around 4 MTPA of CO_2[6].

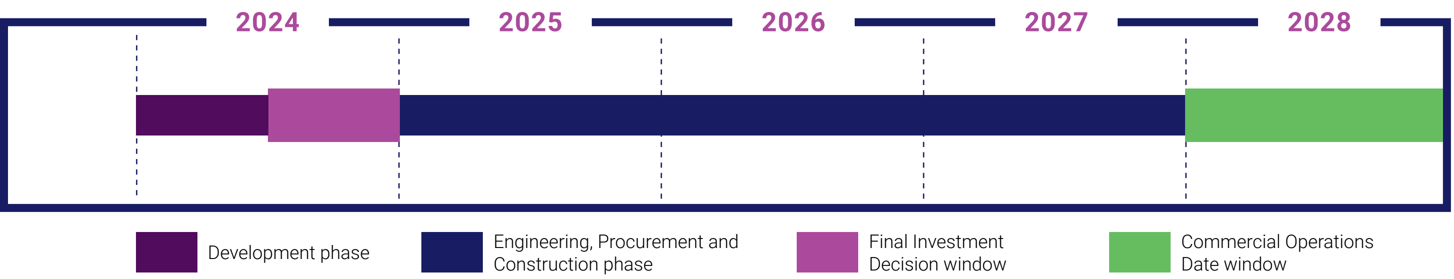
As the NEP pipeline transport system is planned to connect the Teesside and Humber regions to the shared Endurance storage site in the North Sea, other emitters in these two regions will be able to utilise the shared transportation infrastructure. For instance, the connection could be used by operators of bioenergy with CCS, blue hydrogen production, and industrial carbon capture facilities across the region in the future.

Business model support:

NEP will seek financial support from the following government business model: T&S Regulatory Investment (CO_2 transport and storage)[94].

Infrastructure delivery[55]:

Figure 28: NEP indicative project timeline



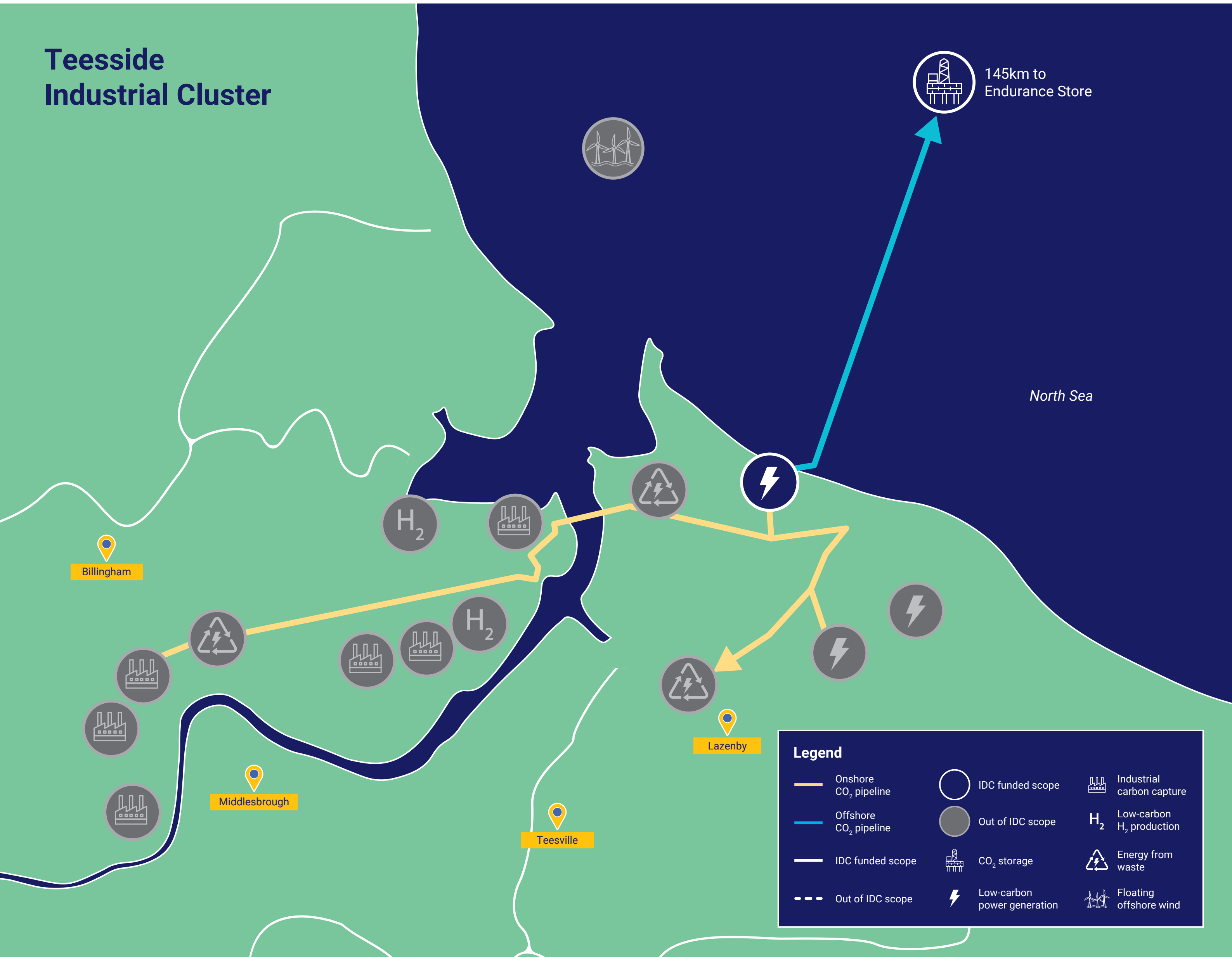
Timelines are indicative based on best estimates. They may vary based on the timing of FID and the cluster sequencing process.

NEP is proceeding in parallel with its initial user project NZT Onshore to enable a cluster FID, which is expected by the Autumn of 2024[55].

Challenges and lessons learnt[85,93]:

- **local environment:** The NEP infrastructure in the Southern North Sea faces the environmental challenge of a fast-eroding coastline and large sand waves, requiring costly seabed rectification to ensure stable pipelines and additional surveys to better understand the geographic area. bp managed this challenge through early data acquisition, collaboration with innovative survey operators and applying a rigorous and systematic approach to assessing risk.
- **technical design in new areas:** The new technology required for CO_2 well design led to technical challenges in well drilling, while the low temperatures experienced from the cooling of CO_2 also needed to be taken into account. A new all-electric subsea system for CO_2 is also being deployed. To mitigate these risks, bp progressed a technology maturation plan and encouraged knowledge sharing across the partnership[97].
- **multi-regulatory approval required:** The project interfaced with multiple government bodies and regulators, who were all developing their own processes for the first wave of CCS projects. The coordination and learning process from all the relevant government bodies and regulators meant that project development timelines were extended a number of times with consequent increases in costs.

Figure 29: Teesside industrial cluster overview



Humber Zero

Overview of IDC-funded scope:

HZ is located in Immingham and the IDC Deployment Project scope, led by VPI includes the following elements[62]:

- **Clean power:** Post combustion technology installed at the VPI Immingham CHP plant.
- **Industrial carbon capture:** Post combustion technology installed at the Phillips 66 refinery.

The total carbon capture capacity of the two projects will be up to 3.8 MTPA[57,60].

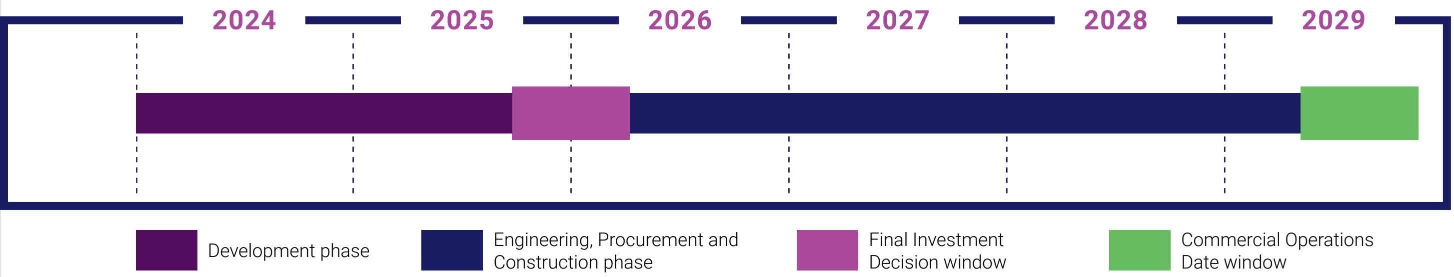
Phillips 66 Limited and VPI are working closely with Harbour Energy in the development of the Viking CCS transport and storage infrastructure in the Humber region[58]. Viking CCS will support and attract lower-carbon industry and investments as the transportation and storage infrastructure can be used by other regional emitters.

Business model support:

The HZ project will seek financial support from the following government business models: Dispatchable Power Agreement (Power CCS), and Industrial Carbon Capture (CO_2 capture facilities)[62]:

Infrastructure delivery[60,98]:

Figure 30: HZ indicative project timeline



Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

Both VPI and Phillips 66 Limited have completed the FEED phase for their capture projects. VPI has selected Worley as the EPC contractor[99] and, similarly, Philips 66 Limited is advancing the project towards the EPC phase. The projects are obtaining the necessary permits and consents, which are currently under review. Subject to obtaining the necessary internal management approvals, both Phillips 66 Limited and VPI are also ready to start business model negotiations with the Government as part of the Track-2 cluster sequencing process.

Challenges and lessons learnt[62,85]:

- **assessing technology options:** Due to the unique first-of-a-kind nature of the project, few references were available when choosing technical options for CO_2 capture in the early stage of the project.
- **uncertainty on Track-2 timing:** Humber Zero's ability to progress beyond FEED is limited by the lack of certainty on the timing of the Track-2 process.

Zero Carbon Humber Partnership

Overview of IDC-funded scope:

Zero Carbon Humber is located in the Humber region and is led by Equinor. The IDC Deployment Project key scope includes the following elements[100]:

- **H_2 production:** Equinor H2H Saltend blue hydrogen plant will supply hydrogen to the nearby Triton power station.
- **Fuel switching:** The Triton power station project aims to blend hydrogen and natural gas in the short term and switch to potentially 100% hydrogen in the long term.
- **CO_2 transport:** Onshore pipeline developed by NEP to connect emitters in the region with the NEP offshore transportation and storage network.
- **H_2 transport and storage:** Onshore pipeline developed by Equinor to connect hydrogen production centres with offtakers in the region, including hydrogen storage for the region.

The project targets a hydrogen production capacity of at least 600 MW and an initial carbon capture transport capacity of 17 MTPA via the onshore pipeline[63].

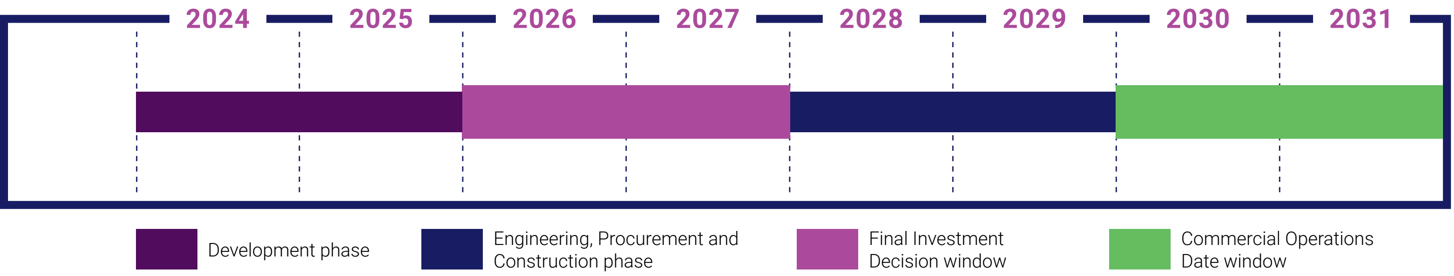
Emitters such as British Steel, Drax power station, Uniper, and SSE Keadby power station can capture and transport their emissions via the CO_2 transportation network[54]. The hydrogen network would connect major hydrogen production sites with potential offtakers such as Keadby Hydrogen Power Station[54]. In the future, other regional emitters would join the shared CO_2 and H_2 transport infrastructure in Humber, thereby achieving wide-scale decarbonisation and fuel switching.

Business model support:

The ZCH project will seek financial support from the following government business model: T&S Regulatory Investment (CO_2 transport), Low Carbon Hydrogen Production, and Hydrogen Transport[101].

Infrastructure delivery[64]:

Figure 31: ZCH indicative project timeline



Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

The various elements of ZCH are ready to enter the FEED phase. This includes the blue hydrogen plant, where Equinor has selected a FEED delivery partner with an option to extend to the EPC and operation and maintenance phase[65]. The onshore CO_2 pipeline scope is progressing in line with the NEP-approved project plan, with FID and COD revised to align with the Track-1 expansion process. The hydrogen pipeline project has been rescoped, with new timelines based on the project being supported through the Hydrogen Transport Business Model allocation process.

Challenges and lessons learnt[85,101]:

- **uncertainty around cluster sequencing process:** No ZCH projects were selected for the cluster sequencing process Track 1 negotiation list. This has created uncertainty on how and when ZCH projects will be able to access the CO_2 T&S network and business models associated with the cluster sequencing process[65].
- **increasing project CAPEX:** The project cost estimate has risen significantly during the project. Equinor minimised exposure to increased EPC costs when tendering the EPC contract by including a high degree of fixed fee contracts, applying index regulation when awarding subcontracts, and assigning responsibility for material quantity to the contractor[102]. It should be noted, however, that without certainty of expected delivery dates, it will be very difficult to realise the benefits of the approach taken, and the contract will most likely have to be renegotiated once clarity on CO_2 T&S access is confirmed.
- **selecting the right contractor:** There can be a discrepancy between the knowledge claimed by engineering contractors and their actual capabilities in the first-of-a-kind projects space. Equinor chose to implement a Pre-FEED design competition between three contractors[103] to get the best overall value and technical solution.
- **inflexibility in the permitting process:** Following the departure of the lead project partner executing the onshore CO_2 and H_2 pipeline scope, the project had to select a new partner and recommence consultation, which adds time and expense.

Figure 32: Humber industrial cluster overview

Scotland's Net Zero Infrastructure (Onshore)

Overview of IDC-funded scope:

SNZI Onshore is located in Scotland and was led by Storegga. The IDC Deployment Project key scope included the following elements[104,105]:

- **Industrial carbon capture:** Carbon capture technology installed at the St Fergus gas terminal.
- **Clean power:** Carbon capture technology installed at the new SSE Peterhead power station.
- **H_2 production:** Greenfield blue hydrogen plant[liii].
- **CO_2 transport:** National Gas Transmission repurposed pipeline for onshore CO_2 transport.
- **CO_2 shipping:** CO_2 shipping infrastructure developed.

The project's scope included a carbon capture capacity of up to 2.9 MTPA[liv] with an initial transport and storage capacity of 5 MTPA[69,71] and an hydrogen production capacity of 300 MW.

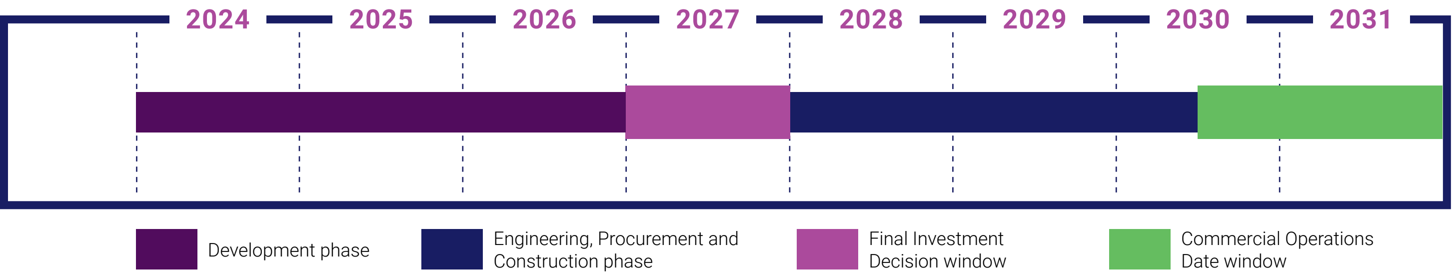
The project studied the potential of repurposing a National Gas Transmission natural gas pipeline. The location of the pipeline means it could transport the captured emissions from Scotland's Central Belt emitters[68]. This includes prospective users such as the INEOS facilities at Grangemouth, the Shell and the ExxonMobil facility at Mossmorran[68], in addition to smaller emitters such as two waste-to-energy plants and a BECCS power plant. This transport infrastructure would provide a viable decarbonisation pathway for Scotland industrial emitters.

Business model support:

The SNZI Onshore projects, should they be selected, would require financial support from the following government business models: Industrial Carbon Capture (CO_2 capture facilities), T&S Regulatory Investment (CO_2 transport), Low Carbon Hydrogen Production and Dispatchable Power Agreement (Power CCS)[104,105].

Infrastructure delivery[71]:

Figure 33: SNZI Onshore indicative project timeline



Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

[liii] Although this subproject received IDC funding, the project is not currently being pursued as an active project following the completion of the IDC programme.

[liv] This capture capacity includes the IDC-funded scope only: CO_2 captured from the Peterhead power station, St. Fergus gas terminal and a blue hydrogen production facility.

Those elements of the SNZI Onshore and Offshore scopes that are being taken forward as part of the Scottish Industrial Cluster are being executed in parallel, with similar timeframes, as part of a full value chain approach. This includes the key milestones such as FID and COD.

A multi-part FEED is still ongoing for the SSE Peterhead power station project, while a previously completed FEED for a portion of the end-to-end SNZI (Onshore and Offshore scopes) is being updated to adapt to the adjusted frame of the cluster sequencing process. The cluster is ready to begin detailed discussions with the Government on their plans for the anchor and build phase as well as business model support, to proceed towards achieving a COD that is aligned with DESNZ's Track-2 ambitions.

Challenges and lessons learnt[85,104,105]:

- **technology and vendor selection limitation:** The project's first-of-a-kind nature has made it challenging to select a technology provider, as only a few companies can deliver CO_2 capture at the scale needed. Likewise, proprietary equipment such as high-pressure CO_2 compressors has been difficult to source due to the limited vendors on the market that can provide these items.
- **permitting preparation:** The numerous subprojects in the overall project scope mean that a myriad of applications must be tracked simultaneously. The project prepared a detailed permitting and consenting strategy for the preparation, screening, scoping, and full submission stages[106]. They also identified the relevant approval authority, which prepared them to track progress across the applications.
- **grid (power) connection constraints:** Like many other large scale infrastructure projects, individual projects require grid connections at different times, for example powering CO_2 compression equipment. However, they have received commercial offers that have grid connections after their targeted CODs. These projects are continuing to engage with stakeholders to identify opportunities to alleviate this.

Scotland's Net Zero Infrastructure (Offshore)

Overview of IDC-funded scope:

Infrastructure considered by SNZI Offshore is located offshore North East Scotland. The IDC Deployment Project scope, led by Storegga, includes the following elements[104]:

- **CO_2 transport and storage:** CO_2 collected at St Fergus from the various sources will be routed to Acorn and East Mey stores via a repurposed offshore pipeline and new CO_2 injection wells.

The project scope explored an initial CO_2 transport and storage capacity of up to 5 MTPA[69].

The SNZI Offshore infrastructure would be designed to receive CO_2 from the SNZI onshore project and additional industrial emitters in Scotland's Central Belt. The CO_2 shipping infrastructure will also allow emitters from other industrial regions such as Teesside, Humber and South Wales or even industries in Europe to ship CO_2 to Acorn stores for permanent storage.

Business model support:

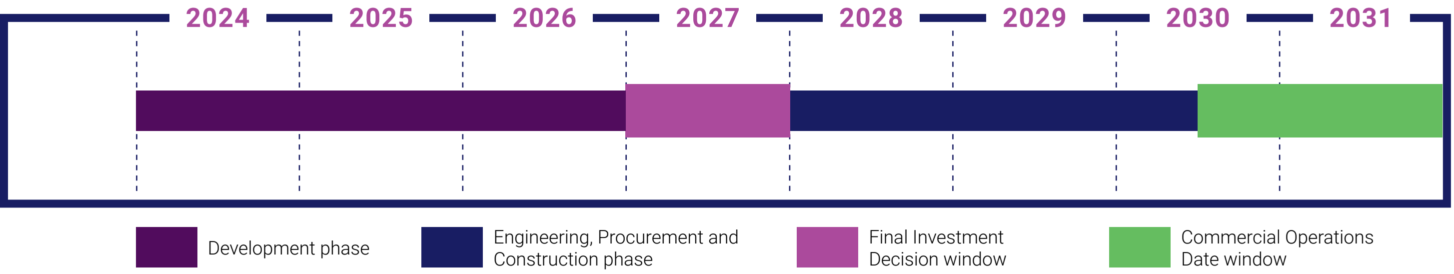
The SNZI Offshore project, should it be realised in its full form, would require financial support from the following government business models: T&S Regulatory Investment (CO_2 transport and storage) and Non Pipeline Transportation (CO_2 shipping)[lv,104].

[lv] Non Pipeline Transportation may be a discrete business model but could also be integrated into existing business models.

Those elements of the SNZI Onshore and Offshore scopes that are being taken forward as part of the Scottish industrial cluster are being executed in parallel, with similar timeframes, as part of a full value chain approach. This includes the key milestones such as FID and COD.

Infrastructure delivery[71]:

Figure 34: SNZI Offshore indicative project timeline

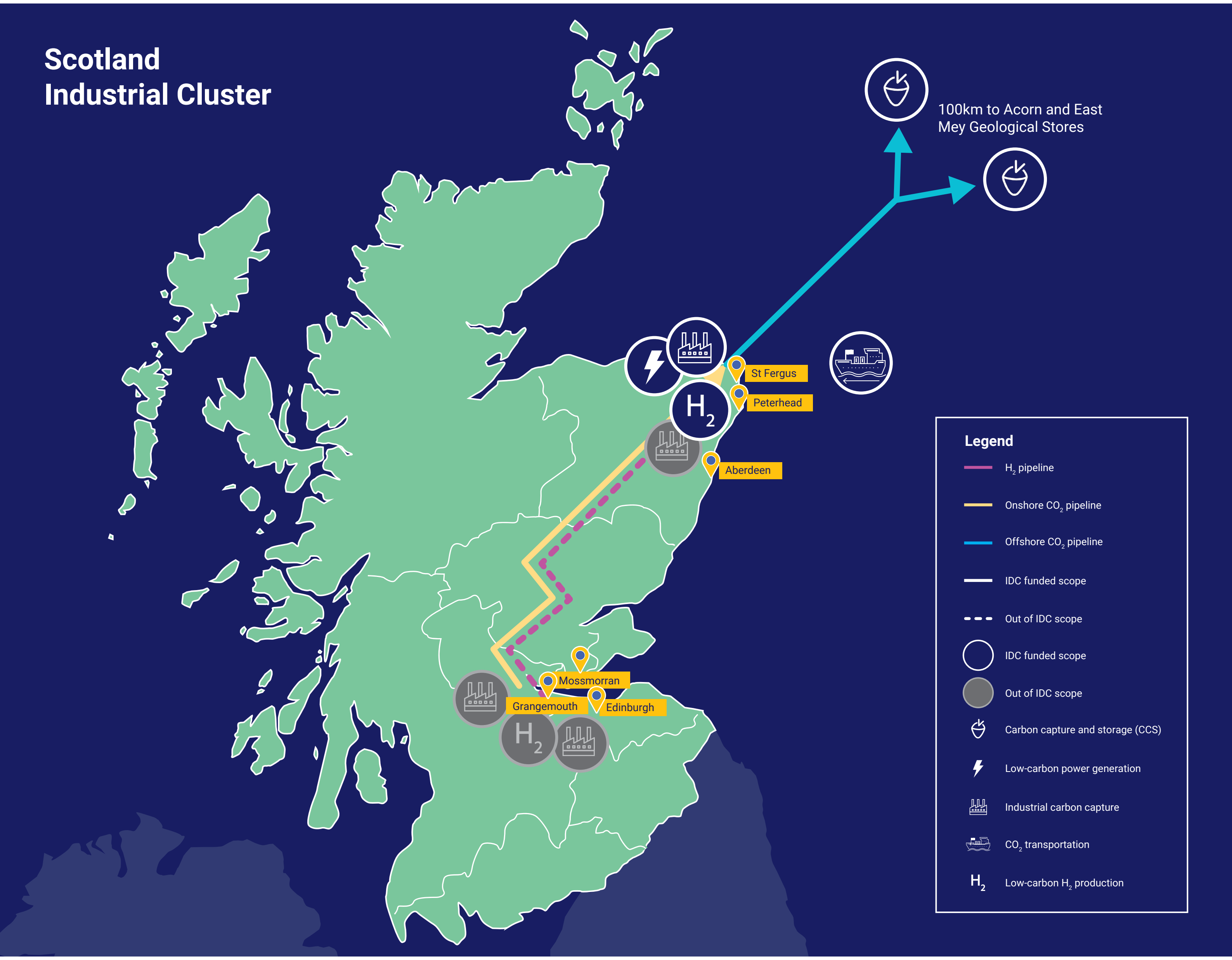


Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

Challenges and lessons learnt[85,104]:

- **technical complexity in repurposing infrastructure:** As some pipelines have not been operational for several decades, pipeline integrity could be a challenge if they are repurposed for CO_2. The project needed to undertake detailed studies and a survey to understand if modifications would be required to repurpose the pipeline for CO_2 service and to extend the operational lifetime of the asset.
- **updates to the CO_2 specification:** The project ambition was to develop the CO_2 specification early in the project phase. However, the specification continued to evolve as the project progressed throughout the FEED, resulting in emitters assessing the impact on the design of their CO_2 capture plants. The continuous need to update the CO_2 specification consumed more time and resources than originally planned.
- **emitter dispatchability:** The expected CO_2 flowrate from the proposed new Peterhead power station will vary as the power station is expected to operate in a dispatchable mode. This may be a challenge for the CO_2 network, which should ideally be operated at a steady state, and mitigation strategies continue to be developed.

Figure 35: Scotland industrial cluster overview



South Wales Industrial Cluster

Overview:

SWIC is located in South Wales and is led by RWE. The IDC Deployment Project key scope includes the following elements[78]:

- **Clean power:** Installation of carbon capture unit at RWE Pembroke power station.
- **H_2 production:** Green hydrogen production facility installed by RWE.
- **H_2 production:** Blue hydrogen production developed by Shell[lvi].
- **H_2 transport:** Onshore hydrogen pipeline (HyLine Cymru) led by Wales & West Utilities.
- **CO_2 shipping:** CO_2 shipping infrastructure developed by Dragon LNG and Shell.

The project targets a carbon capture capacity of up to 2.5 MTPA enabled through the CO_2 liquefication and shipping facility[74] as well as a low carbon hydrogen production capacity of 470 MW[lvii,75,77].

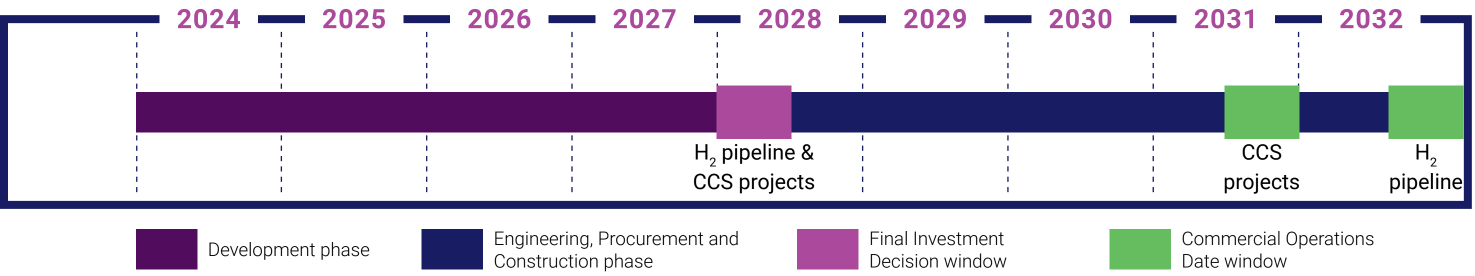
The onshore hydrogen transport infrastructure will connect hydrogen production actors in the region (from blue hydrogen or renewable generation) to industrial offtakers. Thereby enabling the decarbonisation of the South Wales region.

Business model support:

The SWIC project will seekfinancial support from the following government business models: Dispatchable Power Agreement (Power CCS), Non Pipeline Transportation (CO_2 shipping)[lviii], Hydrogen Transport and Low Carbon Hydrogen Production[78].

Infrastructure delivery[77,78]:

***Figure 36: SWIC indicative project timeline**[lix]*



Timelines are indicative based on best estimates and may shift due to several factors, including market conditions, the cluster sequencing process, or the outcome of the business model negotiations.

The individual components of the SWIC Deployment Project have progressed through early engineering design phases. To support the next development phase, the project partners are looking for greater detail and visibility on the timelines associated with the non pipeline transport business model[lviii] and the cluster sequencing process. The above indicative timeline assumes a cluster sequencing process (Track 2) submission in Q1 2025.

[lvi] Although this subproject received IDC funding, the project is not currently being pursued as an active project.

[lvii] Although blue hydrogen production by Shell received IDC funding, the project is not currently being pursued as an active project.

[lviii] Non Pipeline Transportation may be a discrete business model but could also be integrated into existing business models.

[lvix] CCS projects include the following elements: CO_2 capture project, as well as CO_2 liquefaction and shipping. Although the Shell blue hydrogen project received IDC funding, this project is not included because the project is currently not being pursued as an active project. The timeline refers to the initial phase of CCS deployment at SWIC, which was within IDC scope.

Challenges and lessons learnt[85,78]:

- **navigating project changes:** The original project scope was ambitious to meet the scale of the decarbonisation challenge in the region. However, the early involvement of many partners without a clear anchor project made coordinating and planning difficult. The project now places more emphasis on realising the initial key opportunities as a means of enabling cluster wide decarbonisation.
- **gaps in current CO_2 business model:** The project is dependent on CO_2 shipping due to the lack of CO_2 storage nearby the SWIC cluster. The route for incorporating non pipeline transport (including shipping) into the existing DESNZ business models has not been finalised yet, and therefore some aspects of the project are uncertain at present.
- **streamlining processes:** The project requires planning and environmental processes to be delivered in a timely fashion to meet the project timeline. To achieve this, Net Zero Industry Wales and SWIC partners are exploring the potential for development of a co-creation model[79]. This model aims to deliver critical infrastructure engineering, planning, and consenting in parallel. By doing so, processes are streamlined, and necessary regulatory resources are identified and funded[79].

Figure 37: South Wales industrial cluster overview

Appendix 2: Emissions modelling

Approach

1. **Identify the data required:** Identify the projects within scope for the IDC Deployment Projects and IDC-Enabled Projects categories (see assumptions below for more information).
2. **Gather the data:** Using project documentation and other written information shared by the IDC and the IDC Deployment Projects as well as public information, record the CO_2 abatement capacity (capture, transport or storage capacity) or hydrogen production capacity for IDC Deployment Projects and IDC-Enabled Projects. For a limited number of projects, these have been estimated based on high-level engineering principles due to limitation of available data.
3. **Quantify final estimates:** Sum the values for IDC Deployment Projects and IDC-Enabled Projects
4. **Calculate final estimates:** Compute the capacities for CO_2 abatement and low carbon hydrogen production cases:
    - **CO_2 abatement:** Compute the CO_2 capture, transport and storage capacity of the IDC Deployment Projects and IDC-Enabled Projects. Identify the limiting factor (infrastructure) across the CO_2 value chain.
    - **Low carbon hydrogen production:** Compute the low carbon hydrogen production capacities of the IDC Deployment Projects and IDC-Enabled Projects.

Assumptions

- IDC Deployment Projects have been identified and confirmed from project interviews, IDC documentation, and project meetings with IDC.
    - **IDC Deployment Projects:** Projects that received direct funding from the IDC programme.
- IDC-Enabled Projects have been identified based on the approach below:
    - **IDC-Enabled Projects:** Additional low carbon projects in the industrial clusters, which are enabled by the shared infrastructure (e.g. pipelines) developed by the IDC Deployment Projects. These projects are assumed could feasibly come online by 2030. The projects have been determined from a combination of Track-1 shortlisted projects by DESNZ, selected emitter projects by DESNZ, and additional projects within the industrial cluster (from information available online).
    - **IDC-Enabled Projects (Upper Range):** The upper range includes further projects that could be enabled but depend on several factors which make them less feasible to be operational by 2030. The main factors include:
        - projects that are contingent on the deployment of its first phase of operation (e.g., blue hydrogen phase two expansion will only be developed once the first phase of the project has been implemented).
        - availability of shared infrastructure in the industrial clusters (e.g., phase two blue hydrogen projects may depend on hydrogen pipelines being available to supply hydrogen to a regional customer or projects that are part of the wider cluster expansion scenario).

- developing market conditions and regulations that enable further rollout (e.g., development of hydrogen T&S or NPT business models, further allocation rounds in the cluster sequencing process, increased fuel switching demand for hydrogen).
- The projects depend on the deployment of T&S infrastructure and being selected by the Government as part of the cluster sequencing process or hydrogen production allocation rounds. Therefore, not all projects may be fully realised by 2030, which would reduce the reported CO_2 capture, transport, or storage capacity or low carbon hydrogen production capacity[lx].

Data limitations

- **CO_2 capture and low carbon hydrogen production capacity from projects:** The CO_2 capture and low carbon hydrogen production capacity data may not be the latest numbers based on the latest project scope or configuration. Where possible, data has been recorded from project documentation and other written information shared by IDC and the IDC Deployment Projects, main website of the project, or other publicly available information (e.g., environmental impact assessment, project brochure). In a limited number of cases there was no data available, and the capacities were estimated using high-level engineering principles.
- **CO_2 capture and low carbon hydrogen production projects timeline:** The timeline for when the projects will become operational is limited and may not be up to date in public sources, particularly for IDC-Enabled Projects.

IDC Deployment Projects and IDC-Enabled Projects breakdown per region

The table below summarises CO_2 capture capacity by 2030 across industrial regions for IDC Deployment Projects and IDC-Enabled Projects (including the upper range)[lx].

Table 3: CO_2 capture capacity by industrial region for IDC Deployment Projects and IDC-Enabled Projects

Region	IDC Deployment Projects CO_2 capture capacity (MTPA)	IDC Deployment Projects and IDC-Enabled Projects CO_2 capture capacity (MTPA)	IDC Deployment Projects and IDC-Enabled Projects (including upper range) CO_2 capture capacity (MTPA)
North West	1.7	3.6	5.5
Teesside	2.0	6.2	9.0
Humber	5.2	15.7	20.3
Scotland	2.3	3.3	4.4
Wales[lxi]	-	-	-
Total	**11.2**	**28.8**	**39.2**

lx The CO_2 capture capacity from the IDC Deployment Projects and IDC-Enabled Projects are dependent on projects progressing through the development lifecycle to the operational phase. The capacity could be lower if projects do not advance or experience any delays (e.g. in the cluster sequencing process, constrained supply chain, longer timeframe to receive regulatory approvals).

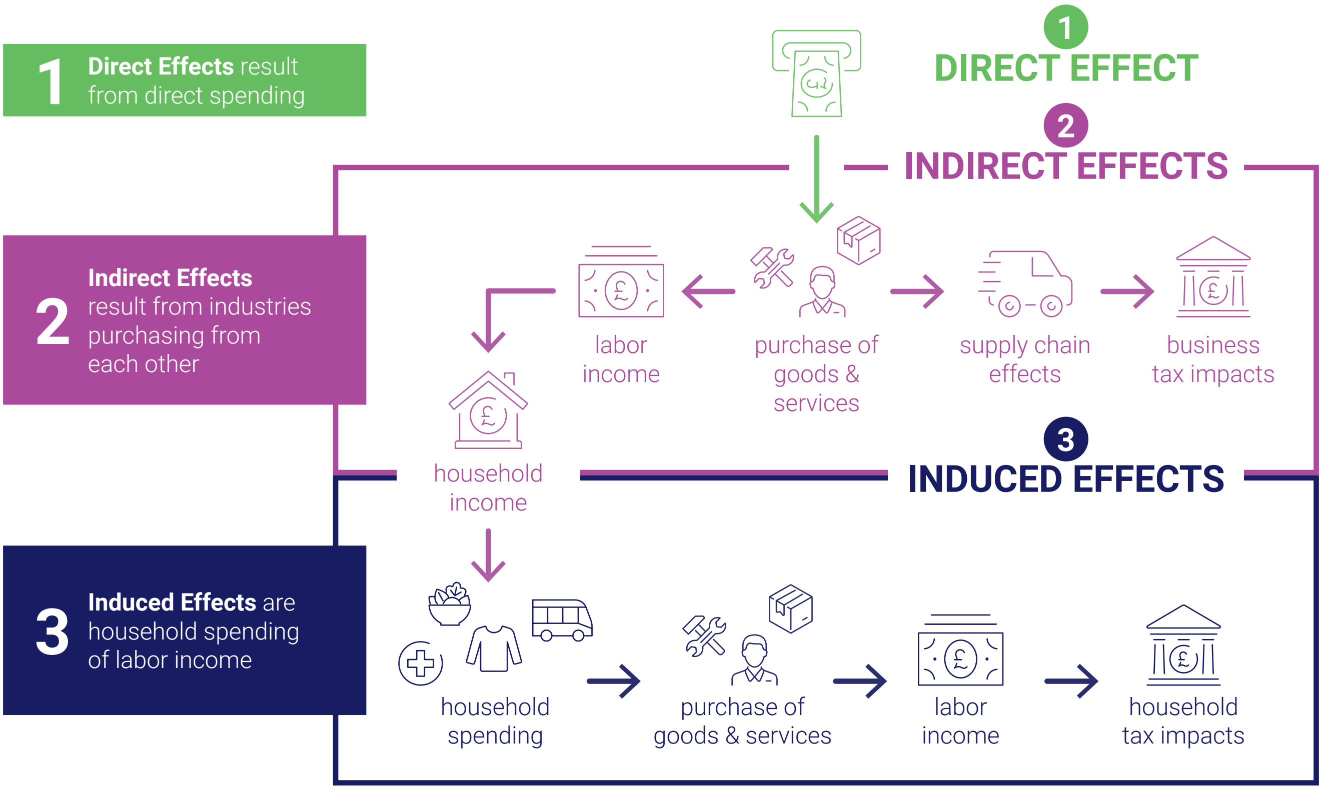
lxi SWIC CO_2 capture capacity excluded as the project timeline assumes a COD of late 2031.

Appendix 3: Economic modelling

Economic impact measures of employment and GVA

The IDC Deployment Projects constructed economic impact models to evaluate the effect of their investments on the UK economy. The input-output (IO) based modelling approach used by most projects allows for the estimation of direct, indirect, and induced impacts.

Figure 38: Definitions of direct, indirect, and induced effects



The impact outputs of these models can be expressed in various economic impact measures. In this case, the nine Deployment Projects have focused on expressing impact in terms of employment and GVA of their investment. Employment impacts are expressed in terms of the number of jobs supported by IDC Deployment Projects. A 'supported' job includes those that are created, safeguarded, and displaced. Jobs are reported on an annual basis, but the value does not distinguish between position type (e.g., 100 jobs per year could be 100 full-time jobs lasting one year, or 200 part-time jobs).

GVA, meanwhile, is a measure of economic output. It captures the contribution to the economy of individual producers, industries, or sectors. GVA only includes the value of additional output generated by these sources, excluding the value of any intermediate inputs used in the production of goods and services (i.e., final demand). In both instances, for both measures, estimates represent the 'potential' economic benefit that the UK could capture, rather than certain amounts.

Approach

1. **Data and documentation collection:** Review public, as well as project and IDC provided documentation for economic impact statements related to employment and GVA.
2. **Aggregate cumulative impacts:** Adjust or transform to impacts as stated in source files such that cumulative impacts (job years, GVA) may be estimated.
3. **Estimate per annum impacts:** Combine estimated cumulative impacts with the number of years modelled to estimate per annum figures for each measure. Rebase prices for GVA to 2024 GBP.

Assumptions

- **Gross effects:** Impacts represent gross effects; i.e., they may include jobs or GVA that could be produced even in the absence of IDC Deployment Projects.
- **Impacts types:** Impacts include direct and indirect effects (i.e., construction and supply chain related impacts of project expenditure), but not induced (i.e., household spending generated by income received as result of project investment).
- **Real outputs:** Output estimates are reported in real prices, taking inflation into account.
- **Discounting:** Costs used in impact estimation are not discounted, unless noted.
- **Leakage:** Impact estimates do not account for leakage (i.e., project expenditure that does not further economic activity within the UK; for instance, project funding spent on imported materials and services) unless otherwise stated. Estimates represent the entire 'potential' economic benefit that the UK could capture.
- **Geographic scope of impact:** UK national, unless otherwise specified.
- **Interpretation of jobs estimate:** Estimate includes jobs created, safeguarded, and displaced. It does not distinguish between full-time and non-full-time employment (e.g., 100 jobs per year could be 100 full-time equivalent (FTE) positions for one year, or 200 part-time positions for one year). Similar assumptions applied for GVA estimates as well (i.e., inclusive of new, safeguarded, and displaced value add, etc.).

Data Limitations

- **Impact scale:** Some IDC Deployment Project impact estimates are representative of a single development (i.e., HZ, ZCH, NZT Onshore), while others represent the impacts of multiple projects (HyNet, SNZI, SWIC, NEP). Where possible, impacts have been scaled down in the latter case to better reflect that which is associated with the IDC-funded component of those wider scale multi-project cluster efforts, but resulting estimates still may not necessarily be a one-to-one match with the impacts of the relevant IDC-funded IDC Deployment Project.
- **Variable approaches:** IDC Deployment Projects' approaches to estimating quantitative economic measures such as employment and GVA vary. While most projects' estimates are input-output modelling based, other forms of impact calculation, such as cost-benefit analysis were used as well.
- **Impacts considered:** The different approaches limit the types of impacts that are reported by IDC Deployment Projects in some cases (e.g., only direct employment and GVA estimates have been derived for SWIC as the core analysis approach used by the project is a cost-benefits analysis rather than economic impact modelling done by the other projects; further, most projects did not report development phase impacts, thus only impacts for construction and operations phases of projects are considered).
- **Timing of analysis:** Some analyses conducted earlier in the Deployment Project development process utilise timing assumptions around when planned developments may reach various phases of work that are no longer applicable given changes within the project since the publication of the analysis or in current wider market conditions. As such, the aggregation of individual IDC Deployment Project impacts only show indicative timings for how annual impacts are distributed over time (a 30-year period is supposed), without being able to denote a specific year in which they are expected.

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