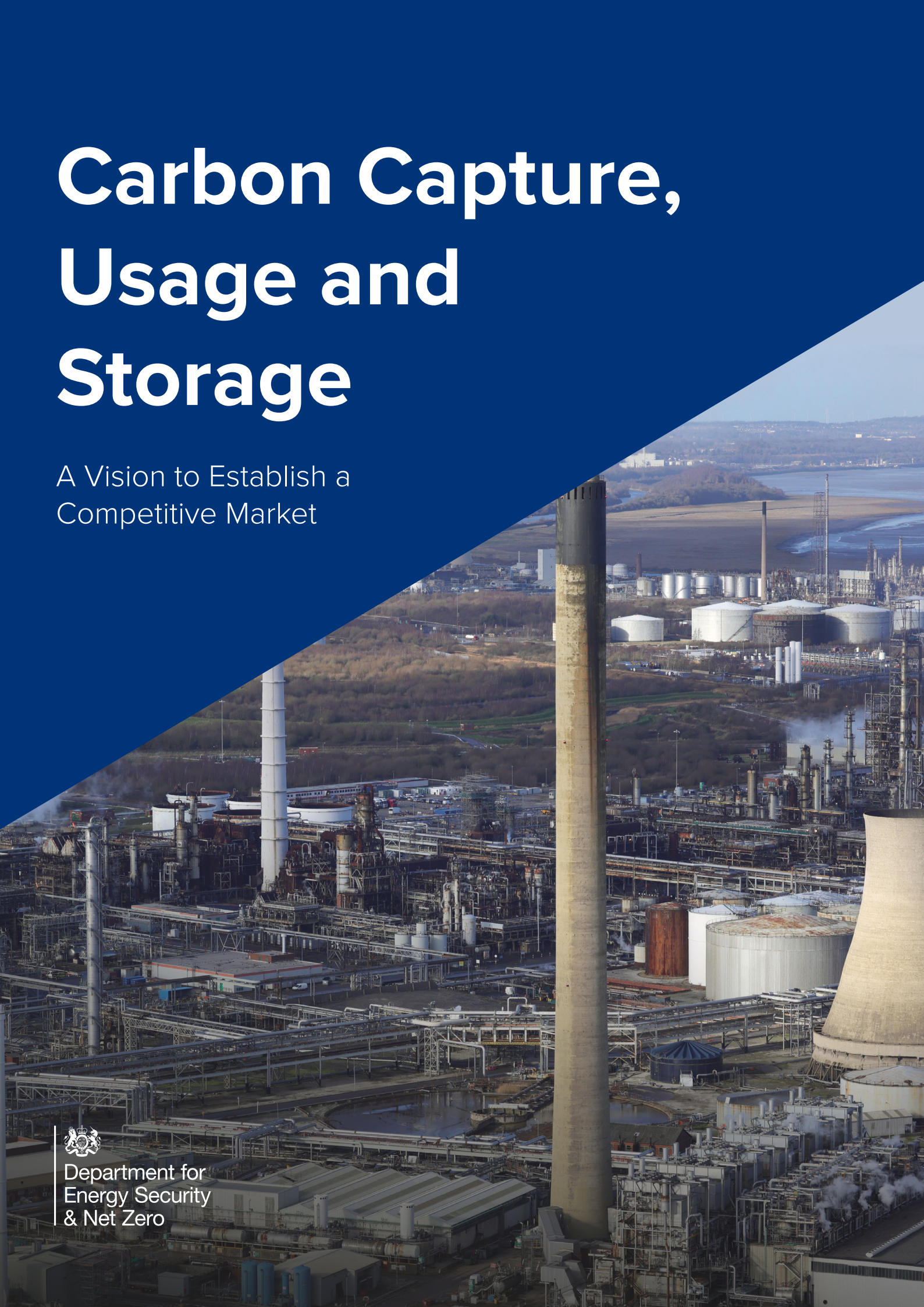
Carbon Capture, Usage and Storage

A Vision to Establish a Competitive Market



Department for Energy Security & Net Zero

Carbon Capture, Usage and Storage

A Vision to Establish a Competitive Market

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Ministerial Foreword

Carbon Capture, Usage and Storage (CCUS) will be a game-changer for the UK's energy transition. With capacity to safely store up to 78 billion tonnes of CO_2 under our seabed – one of the largest such capacities in the world – we plan to develop CCUS into a highly valuable national asset that will help us reach net zero and boost our economy by up to £5 billion per year by 2050.

We have already decarbonised more than any other major economy since 1990, reducing emissions by nearly half while growing our economy by two thirds. Over the past 13 years, for example, the amount of electricity coming from renewables has increased fivefold. But CCUS gives us new options, such as helping heavy industry to be part of our net zero future, and the UK offering CO_2 storage services to other countries. We have the unique geology, infrastructure and know-how to lead the world in capturing and permanently storing carbon. On top of the environmental benefits, we will capitalise on the economic opportunities of carbon capture and storage.

In March 2023, the Chancellor announced up to £20 billion to support the initial deployment of CCUS. We want to create four CCUS clusters by 2030, storing 20 to 30 megatonnes of CO_2 a year, delivering 50,000 jobs and helping level up the UK. To support this, we have also announced the first eight projects of the 'first-of-a-kind capture networks' in North East England, North West England and North Wales, with plans to expand Track-1 clusters and establish Track-2 clusters in North East Scotland and the Humber.

But this is only the start, in this document, we set out a vision of what a market focused CCUS sector might look like, tapping into innovation and business know-how to drive the scale up and acceleration of CCUS deployment during the 2030s. That means creating a competitive market by the middle of the next decade that reduces costs and allows investors to build a thriving and self-sustaining CCUS industry. In this way, the private sector can drive the development of carbon capture, creating jobs and economic growth, and helping us achieve our carbon budget targets.

This is pioneering work, requiring close collaboration between government, industry and local regions where carbon capture clusters are forming. There will be significant challenges as we develop a viable pathway for CCUS, but the rewards will be unprecedented. By investing heavily in the early development of CCUS clusters, and today setting out our longer-term vision for a competitive market, we can meet those challenges and seize those rewards, so CCUS can achieve its full economic opportunity, and the UK can take a giant leap towards net zero.

Rt Hon Claire Coutinho MP

Secretary of State for Energy Security and Net Zero

Lord Callanan

Minister for Energy Efficiency and Green Finance

Executive summary

Establishing a UK CCUS market which will unlock economic opportunities

Since 2021, we have established the roll-out process and identified the first four Carbon Capture, Usage & Storage (CCUS) clusters for deployment in the UK by 2030. The government has committed up to £20 billion to establishing a CCUS sector in the UK, which will help unlock economic opportunities and will include significant investment in CCUS projects supporting up to 50,000 jobs.[1] Tapping into our 78 billion tonnes storage potential in the North Sea and assets can help us to maximise the economic opportunity from the transition to net zero and help create a commercial and competitive market.

There is an opportunity for UK supply chains in CCUS to develop new capabilities and secure a substantial global market share for CCUS technologies. A successful UK supply chain is key to creating and sustaining high-skill, high-value jobs and supporting low carbon growth in industrial clusters. The Carbon Capture and Storage Association's (CCSA) Supply Chain Good Practice Guidance Document includes a headline voluntary content ambition of 50% UK content.

To enable the global advancement of CCUS, the UK government is leading and convening international engagement on CCUS through multilateral forums and bilateral relationships. Through this, we are committed to learning from others and sharing our own experiences of deploying CCUS as well as working with others to overcome the barriers to fully deploying CCUS.

Transition to net zero

The UK's independent advisor on climate change, the Climate Change Committee (CCC), has said that CCUS is a 'necessity, not an option' for the transition to net zero.[2] Furthermore, the International Energy Authority (IEA) has said that CCUS is an essential component of a global transition to net zero, with an estimated 1 billion tonnes of storage capacity being required globally by 2030 for a net zero pathway consistent with 1.5 degrees.[3]

In a future net zero world, we will still need materials such as cement, steel, and chemicals. For many of these sectors, CCUS is the only viable route to decarbonise at the scale required for us to meet our targets. CCUS is key in creating new sustainable energy for the future. By using CCUS, we can generate more low carbon power and create a responsive clean energy system. CCUS can be used to decarbonise the production process for hydrogen and other low carbon fuels and to clean up

[1] Department for Business, Energy & Industrial Strategy (2019), 'Energy Innovation Needs Assessments', https://www.gov.uk/government/publications/energy-innovation-needs-assessments

[2] The Climate Change Committee (2019), 'Net Zero: the UK's contribution to stopping global warming', https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

[3] International Energy Agency (2023), 'Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach', https://iea.blob.core.windows.net/assets/13dab083-08c3-4dfd-a887-42a3ebe533bc/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf, p.132

our waste. Emerging technologies are also being developed that remove carbon directly from the atmosphere and create negative emissions; these will be essential for the UK to achieve net zero emissions by 2050.

Establishing a commercial and competitive UK CCUS market

Our vision is to make the UK a global leader in CCUS, creating a self-sustaining CCUS sector that supports thousands of jobs and reduces emissions to ensure a better environment for future generations.

We will make this vision a reality through the development of a commercial and competitive CCUS market, where we envisage the roles of government and industry evolving over time, through the following three phases:

- Market creation: Getting to 20 to 30 mtpa CO_2 by 2030
- Market transition: The emergence of a commercial and competitive market
- A self-sustaining CCUS market: Meeting net zero by 2050

Currently, we are progressing with the market creation phase with Track-1 and Track-2 cluster development and establishing a regulatory framework for the CCUS sector. Track-1 is in the process of negotiations. Track-1 expansion is being launched with the opening of an application window to expand the HyNet cluster, in parallel to this document to further strengthen the roll out. Track-2 will aim to establish two new CO_2 transport networks around Acorn (St Fergus, North East Scotland) and Viking CCS (the Humber) CO_2 storage sites. Government have updated on Track-2 simultaneously, setting out our proposed allocation approach of an 'anchor' and 'buildout' phase and high-level timelines, with the anchor project submission window opening in early 2024.

Beyond 2030, a significant ramp up in the commercial deployment of CCUS will be required in the UK to support the emergence of the sector, further support individual sector decarbonisation routes and deliver the expected contribution to Carbon Budget 6. By the mid 2030s, the amount of CO_2 annually stored may need to increase to at least 50 megatonnes per annum (Mtpa).[4] To achieve this, it is likely that the CCUS sector will need to increase the annual amount of CO_2 stored by at least 6 Mtpa each year from 2031.

This document sets out the steps to transition from the market creation phase to the market transition phase, where we envisage the emergence of a commercial and competitive market that efficiently accelerates deployment whilst driving costs reduction and reducing the degree of government support needed. In 2024, we intend to take forward work to enable the market frameworks necessary to support a market transition to a commercial and competitive market, including:

- Launch a consultation on the design of an enhanced competitive allocation process for capture contracts.
- Work with industry and wider stakeholders to consider the strategic direction for CO_2 transport networks, including developing an understanding of the degree of strategic co-ordination needed and any potential role for the Future System Operator.

[4] Department for Energy Security and Net Zero (2023), 'Powering Up Britain: Net Zero Growth Plan', https://www.gov.uk/government/publications/powering-up-britain

- Publish a call for evidence on how government envisages non-pipeline transport to be delivered in the UK.
- Review the current regulations regarding third-party access to infrastructure to ensure they are fit for purpose for the regulated CO_2 transport network.
- Working with stakeholders to develop policies to secure sufficient subsurface storage capacity, including to:

  (a) support the North Sea Transition Authority (NSTA), The Crown Estate and Crown Estate Scotland as they continue to explore the optimal approach to carbon storage licensing and leasing,

  (b) continue to streamline and strengthen the regulatory processes and interfaces for CO_2 stores,

  (c) support the NSTA and other stakeholders on licensing and appraisal strategy to ensure sufficient CO_2 injectivity is available to meet projected demand,

  (d) develop options to deliver a more competitive market for CO_2 transport and storage services and

  (e) enable the management and delivery of the multiple government targets that place a demand on the finite resources of the seabed.

- Work with stakeholders to explore what actions may be required to enable a new commercial framework to support international imports.
- Engage with industry to consider the role of Carbon Capture and Usage within the CCUS framework, where CO_2 is permanently abated via non-geological storage.
- Publish the Green Jobs Plan – a roadmap to deliver a skilled and sufficiently sized workforce.
- Establish an industry working group on the identification and timely adoption of cost reduction opportunities.
- As part of the Autumn Statement on 22 November 2023, the Chancellor announced a £960 million Green Industries Growth Accelerator to support the expansion of strong, home-grown, clean energy supply chains across the UK, including CCUS. This will enable the UK to seize the significant growth opportunities presented by our transition to Net Zero.

These actions will help to further the development of the CCUS sector, driving the sector towards Phase Two: a market transition. The following chapter outlines the wide-ranging opportunities which could be afforded to the UK by the successful development of the UK CCUS sector.

Chapter 1:

Opportunities of a New UK CCUS Sector

A UK CCUS sector will unlock economic opportunity

Carbon Capture, Usage and Storage (CCUS) is the process of capturing carbon dioxide for usage or for permanently storing it, deep underground, where it cannot enter the atmosphere. The UK is leading the development of CCUS and with the pace of CCUS activity accelerating across the globe, the UK has been rated amongst the top five nations globally for CCUS readiness.[5]

We have leapt from a standing start in 2021 to our current position, whereby we are taking forward the development of four CCUS clusters: HyNet (North West England and North Wales), East Coast Cluster (Teesside and the Humber, NorthEast England), Acorn (North East Scotland) and Viking CCS (the Humber).

We have announced up to £20 billion of funding to support the early deployment of CCUS in the UK. For CCUS to realise its full potential there is also a need for significant private sector investment and the financial gain could be significant. A recent supply chain report said that UK carbon capture and storage could be worth £100 billion to local manufacturing employers.[6]

We have focused on creating a stable, long term, supportive policy environment for CCUS deployment in the UK. Through the Energy Act 2023, we have established groundbreaking legislation which creates a robust regulatory framework for CCUS, managing cross-chain risks and enabling the deployment of projects. The CCUS business models are recognised for the unique way in which they will support significant investment in CCUS projects and thus the deployment of CCUS.[7]

There is a role for CCUS in supporting businesses to ensure a just transition to net zero. Our approach to establishing CCUS will create economic opportunity across the UK with up to 50,000 jobs that could be supported by 2030.[8] Individual clusters also estimate either supporting or creating thousands of jobs[9] in our industrial heartlands. UK Research & Innovation's (UKRI) recent publication, A Plan for UK Industrial Decarbonisation, noted that

[5] Statista (2023), 'The Carbon Capture and Storage (CCS) Readiness Index Worldwide in 2023', https://www.statista.com/statistics/1411813/carbon-capture-and-storage-readiness-index-by-country-worldwide/

[6] The UK Offshore Energies Association (2022), 'CCUS Supply Chain Report', https://oeuk.org.uk/product/ccs-supply-chain-report-2022/

[7] IEA (2023), 'How new business models are boosting momentum on CCUS', https://www.iea.org/commentaries/how-new-business-models-are-boosting-momentum-on-ccus

[8] BEIS (2019), 'Energy Innovation Needs Assessment', https://assets.publishing.service.gov.uk/media/5dc5872be5274a4f2286fc76/energy-innovation-needs-assessment-ccus.pdf

[9] 1. East Coast Cluster (2023), 'East Coast Cluster - Decarbonising Britain's Historic Engine Room', https://eastcoastcluster.co.uk/ (P2)
2. HyNet (2021), 'Potential Economic Impacts of the HyNet North West Project', https://hynet.co.uk/wp-content/uploads/2021/06/economic-impacts-report-040518.pdf (P2)
3. Viking CCS (2023), 'Harbour Energy and bp agree to develop the Viking CCS project', https://www.vikingccs.co.uk/news/harbour-energy-and-bp-agree-to-develop-the-viking-ccs-project
4. The Acorn Project (2021), 'Scottish Cluster expected to deliver 20,600 jobs in the next decade' https://www.theacornproject.uk/news-and-events/scottish-cluster-expected-to-deliver-20-600-jobs-in-the-next-decade

each Industrial Decarbonisation Challenge (IDC) cluster expects to create or safeguard up to tens of thousands of jobs.[10] These projections illustrate the scale of the potential economic benefit provided by CCUS, both with respect to employment and general economic growth.

The UK has significant geological assets, with the UK Continental Shelf (UKCS) potentially having enough capacity to safely store up to 78 billion tonnes of carbon, one of the largest potential CO_2 storage capacities in Europe. The UK is fortunate to have sufficient storage to sequester our domestic emissions whilst also offering potential storage to international emitters, providing additional economic opportunities. Tapping into these North Sea resources and assets can help us maximise the economic opportunity inherent in the transition to net zero. The geology and its proximity to major emission centres provides a great opportunity for the UK to lead this new industry.

A technology critical to achieving net zero

The Climate Change Committee (CCC), the UK's independent advisor on climate change, has said that CCUS is a 'necessity, not an option' for the transition to net zero.[11] In their latest progress report, the CCC said that CCUS will need to play a role in the decarbonisation of many sectors: notably industry, electricity generation and fuel supply.[12] Furthermore, the International Energy Authority (IEA) has said that CCUS is an essential component of a global transition to net zero, with an estimated 1 billion tonnes of storage capacity being required globally by 2030 for a net zero pathway consistent with 1.5 degrees.[13]

CCUS is essential for industry to decarbonise. In the future net zero world, we will still need materials such as cement, steel, and chemicals. For many of these sectors, CCUS is currently the only viable route to decarbonise at the scale required for us to meet our targets.

CCUS is critical for energy security. By using CCUS, we can build more dispatchable gas-fired power plants and Bioenergy with CCUS power plants (power BECCS), complementing renewable generation to ensure energy security that aligns with our net zero ambitions.

CCUS is key in creating new sustainable fuels for the future. CCUS can be used to decarbonise the production process for hydrogen, which can provide low carbon energy across the economy. CCUS can also be used in the production process for low carbon fuels, such as sustainable aviation fuels, which are significantly less carbon intensive compared to current jet fuels.

CCUS is also needed to reduce emissions from our residual waste sector. There are government policies in place aimed at reducing waste by preventing waste from being produced in the first instance and by increasing recycling and reuse. For the remaining residual waste, energy generation and the application of CCUS to capture the carbon that would otherwise be emitted into the atmosphere are ways to reduce the impact of managing and utilising the waste we do produce.

[10] UK Research and Innovation, 'Enabling Net Zero: A Plan for UK Industrial Cluster Decarbonisation', https://www.ukri.org/wp-content/uploads/2023/09/IUK-131023-UKRI_EnablingNetZero.pdf (P25)

[11] The Climate Change Committee (2019), 'Net Zero - The UK's contribution to stopping global warming', https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

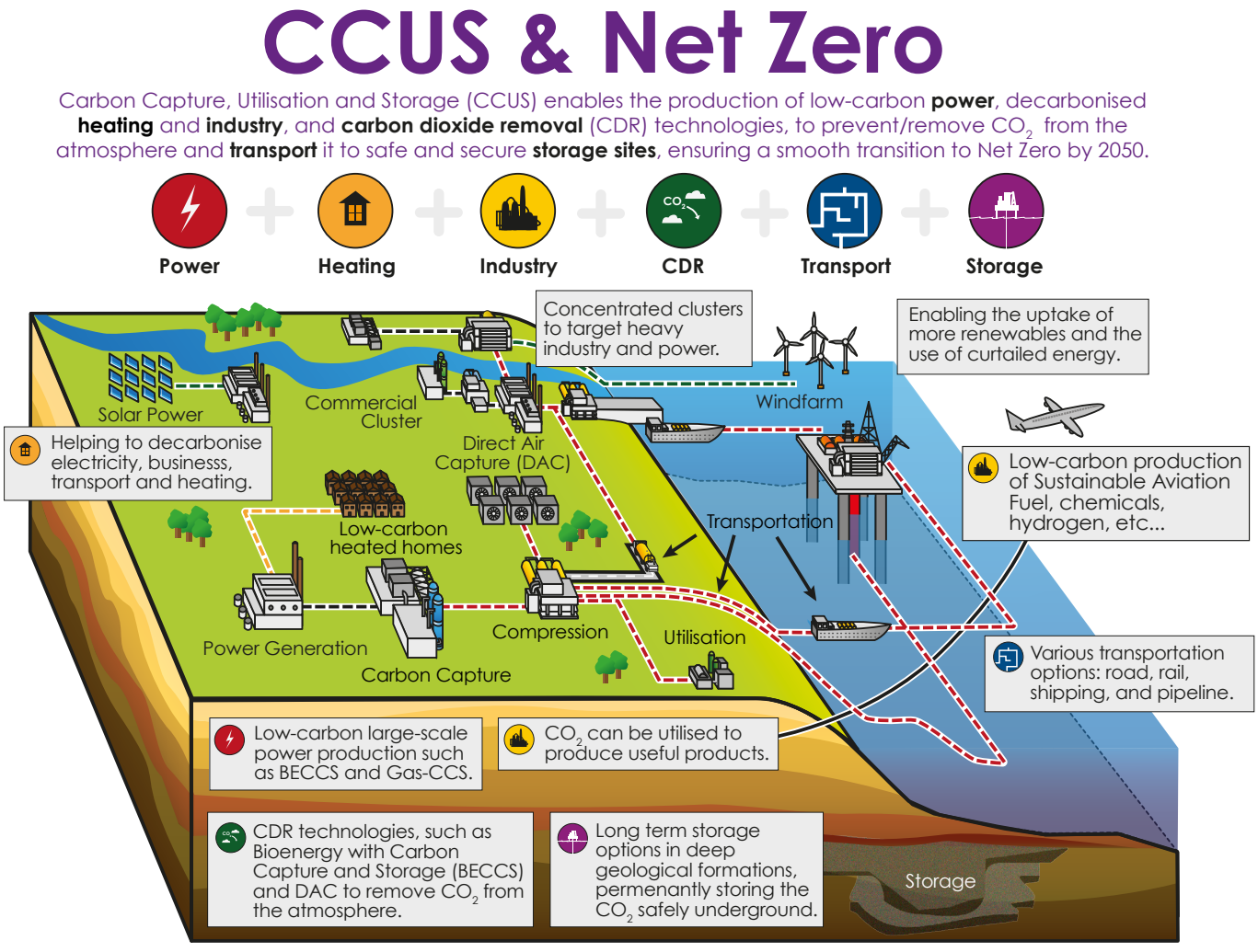
[12] The Climate Change Committee (2023), '2023 Progress Report to Parliament', https://www.theccc.org.uk/publication/2023-progress-report-to-parliament/

[13] International Energy Agency (2023), 'Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach', https://iea.blob.core.windows.net/assets/13dab083-08c3-4dfd-a887-42a3ebe533bc/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf, p.132

CCUS is essential for all these sectors, but to get to net zero we will also have to take advantage of emerging technologies that remove CO_2 directly out of the atmosphere and create negative emissions.[14] Foremost amongst these technologies is Direct Air Capture, which will be critical to deploy at scale to get us to net zero.

A future CCUS system will therefore enable multiple sectors to connect to a CO_2 transport network that will enable carbon to be transported from an emitting facility to a geological storage location, where the carbon will be safely stored permanently to ensure a cleaner environment for future generations.

Figure 1: Explaining CCUS

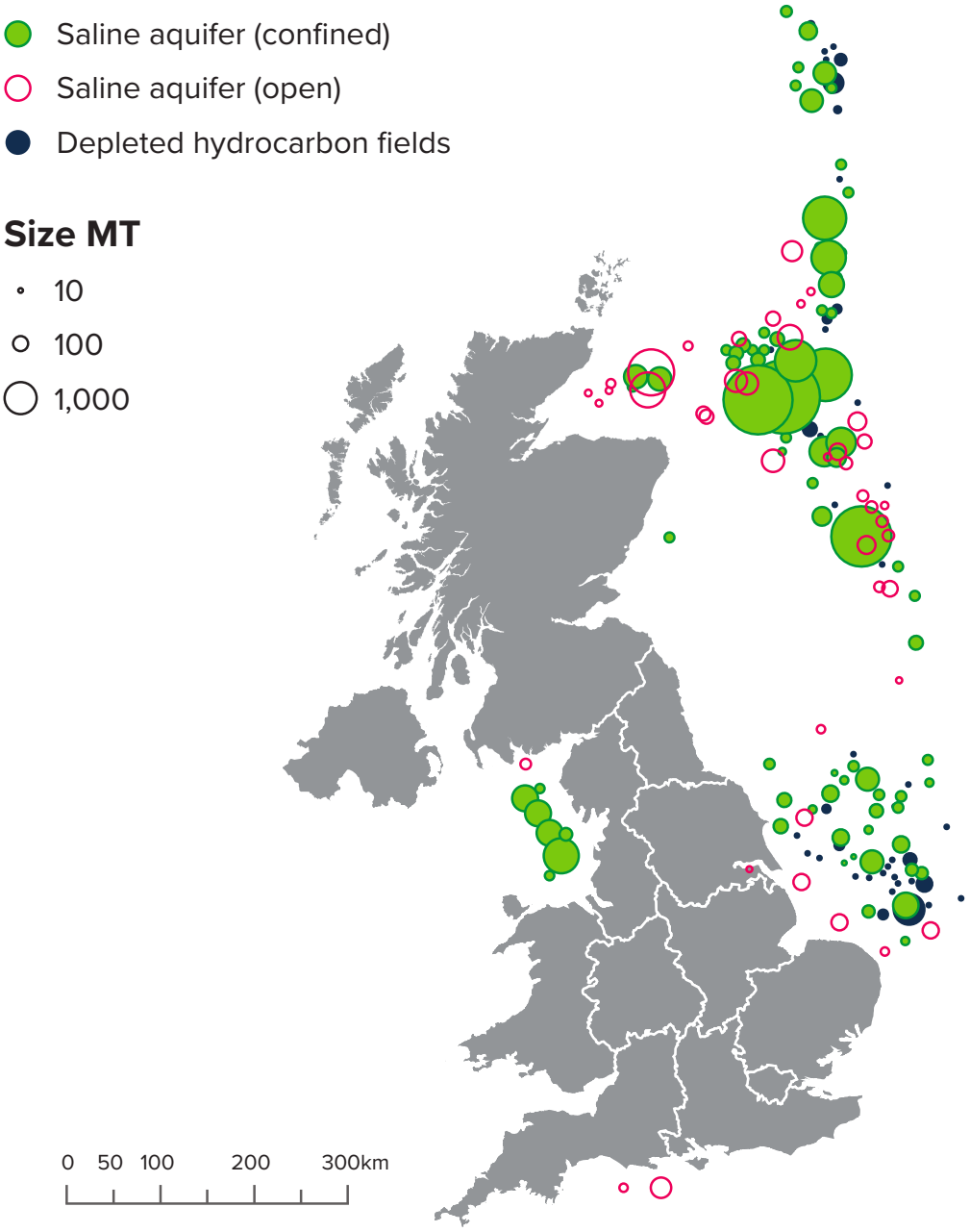


Credit: Dr Mathew Dennis Wilkes

[14] For a technology to deliver a negative emission it must remove more greenhouse gases from the atmosphere than are generated from the carbon removal process and feedstock production if appropriate (e.g BECCS), i.e. the process is net negative.
Our criteria for robust negative emissions is threefold:

- Net negativity: more carbon is removed from the atmosphere than is generated in a GGR process;
- CO_2 source: CO_2 must be captured directly from the atmosphere or seawater (via chemical, biological or geochemical means);
- Permanence: the removed carbon is contained in a highly-durable store

Figure 2: Map showing storage potential in the North Sea



Storage units with less than 20 Mt of storage capacity are not included in this figure

An opportunity for UK supply chains

There is an opportunity for UK supply chains to develop new capabilities and secure a substantial global market share for CCUS technologies. The government is clear that a vibrant and successful UK supply chain is key to creating and sustaining high-skilled, high-value jobs and supporting low carbon growth in industrial clusters. To achieve this, government and industry must work closely together to address key strategic issues and barriers to investment, enabling UK supply chains to realise the economic benefits of a new CCUS sector. CCUS can then unlock further economic opportunities in sectors that are dependent on CCUS technologies such as cement.

Announced in the Autumn Statement in November 2023, the Green Industries Growth Accelerator is a £960 million package which will bolster UK manufacturing capacity and strengthen supply chains in high opportunity sectors like low carbon hydrogen, CCUS, electricity networks, nuclear and offshore wind. Throughout 2024 we will work with industry to carry out market engagement and develop an appropriate delivery mechanism that will maximise the economic opportunity for the UK, support key strategic elements of the supply chain and sustain jobs across our industrial heartlands.

The CCUS industry, through the Carbon Capture and Storage Association (CCSA), published CCUS Supply Chain Good Practice Guidance in July 2023,[15] setting out its strategy to build a domestic supply chain for the deployment of the first Track-1 CCUS clusters, as well as for the subsequent ramping up of the UK's CCUS industry to serve a major and growing international demand. The document sets out a series of industry-led commitments, including its approach to promoting UK supply chain opportunities, creating and sustaining jobs through CCUS projects and investment in training and skills. The guidance also sets out a pathway for delivering UK content ambitions in CCUS projects that are consistent with those put forward in the North Sea Transition Deal (NSTD), including a headline voluntary local content ambition of 50%.

The government welcomes this industry-led approach. It builds on our work over the last year to identify potential opportunities to build UK supply chains for CCUS and capture maximum economic value in the UK. We are also building our evidence base to understand where best to focus efforts to realise the maximum benefit. In July 2023, we published two studies on opportunities for economic growth in the UK's CCUS industry[16] and industrial carbon capture, usage and storage supply chain capabilities.[17] The studies outlined that:

- The onshore equipment cost of delivering our ambition to capture 20 to 30 megatonnes (Mt) of CO_2 per year by 2030 could be in the order of £3 billion to £4.5 billion and that the UK supply chain has significant opportunities to deliver on a significant portion of this spend. The capital spend in a typical capture plant could include around £20 million spent on column vessels, £4 million on column internals and £2 million on heat exchangers. These components have been identified as high value opportunities in the CCUS value chain where the UK has the potential to hold significant capacity in their manufacture and fabrication.

[15] Carbon Capture and Storage Association (2023), 'CCSA Launches New CCUS Supply Chain Strategy', https://www.ccsassociation.org/all-news/ccsa-news/ccsa-launches-new-ccus-supply-chain-strategy/

[16] Department for Energy Security and Net Zero (2023), 'Opportunities or Economic Growth in the UK's CCUS Industry', https://www.gov.uk/government/publications/opportunities-for-economic-growth-in-the-uks-ccus-industry

[17] Department for Energy Security and Net Zero (2023), Industrial carbon capture, usage and storage (CCUS): UK supply chain capabilities', https://www.gov.uk/government/publications/industrial-carbon-capture-usage-and-storage-ccus-uk-supply-chain-capabilities

Alongside the opportunities presented in the manufacture of key components, there are significant strengths for the UK in engineering design, construction and construction management services. The UK has a long tradition of providing these services, which make up a significant part of the CCUS supply chain. This therefore represents a major economic opportunity for the UK, playing to a nationwide strength in high value technical design.

The UK also has the potential to become a world-leader in the provision of CCUS packages.[18] The rapidly developing supply chain already contains several UK companies which offer capture packages for industrial customers. We anticipate the emergence of a wider range of companies with competitive offerings as the sector continues to grow.

We are working to improve how we make best use of our offshore resources in an integrated way. The NSTA has launched the Energy Pathfinder[19] to provide real-time visibility of activity for new oil and gas field developments, decommissioning and projects to support the energy transition on the UK Continental Shelf (UKCS), including CCUS. This will help supply chain companies target the UKCS contract opportunities more effectively and give service companies confidence to invest in skills and new technologies.

The UK will also leverage its expertise internationally and generate significant economic benefits from exports. McKinsey analysis has found that CCUS uptake needs to grow by a factor of 120 by 2050 for countries to meet their net zero commitments, with some estimates ranging from 6 to 10 billion tonnes per annum of CO_2 captured.[20] There is a potential for £4 billion to £5 billion in Gross Value Added from UK CCUS exports by 2050,[21] which includes exporting our expertise and storage to other countries. The geology and the proximity to major emissions centres in north and west Europe provides the appropriate environment for the UK to lead this new industry to support international emissions reductions.

To capitalise on the UK's world-leading potential, government and industry must work together to accelerate the supply of a skilled workforce for our low carbon sectors and provide support for workers in high carbon industries to transition into CCUS-related jobs. This is why we launched the CCUS Task and Finish Group, within the Green Jobs Delivery Group which has gathered evidence concerning the anticipated skills gaps, effectiveness of current industry and government support and future demand. This evidence will feed into the Green Jobs Plan, which government has committed to publishing in 2024 and which will inform future government interventions.

We will enable sectors to transition and develop a skilled workforce through support of the NSTD, a key commitment of which is to support the transition of existing parts of the oil and gas workforce to ensure that people and skills are transferable across the wider energy sector.[22]

[18] Several UK companies offer CCUS packages, which are capture plants as packages of assembled components on modules/skids, occasionally also offering maintenance and operational services. These companies cover many different capture technologies, including, pre-, post- and oxyfuel combustion and vary in size with some new small-medium-enterprises (SMEs) and other, larger, established engineering companies offering technologies.

[19] North Sea Transition Authority (2023), 'Energy Pathfinder', https://www.nstauthority.co.uk/regulatory-information/supporting-the-supply-chain/pathfinder/

[20] McKinsey & Company (2022), 'Scaling the CCUS industry to achieve net-zero emissions', https://www.mckinsey.com/industries/oil-and-gas/our-insights/scaling-the-ccus-industry-to-achieve-net-zero-emissions

[21] Department for Business, Energy and Industrial Strategy (2019), 'Energy Innovation Needs Assessments', https://www.gov.uk/government/publications/energy-innovation-needs-assessments

[22] Department for Business, Energy & Industrial Strategy (2021), 'North Sea Transition Deal', https://www.gov.uk/government/publications/north-sea-transition-deal

To achieve this, government has supported the development of an Integrated People and Skills Strategy, which was published by the skills body OPITO in May 2022.[23] The Strategy identified the current lack of recognition of standards among different offshore energy sectors as a barrier inhibiting workers from pursuing opportunities across the offshore energy industry. Good progress is being made to address this by aligning cross-sector energy training, in particular, OPITO has been developing a digital energy skills passport with funding from the Scottish Government.

In addition, we will work to ensure that investors into the CCUS sector are aware of the benefits of Freeports,[24] including those looking to invest in the supply chain as well as along the value chain, including for instance in the next iteration of the CCUS Investor Roadmap, used with investors to showcase UK investment opportunities.[25]

An opportunity to advance CCUS internationally

CCUS is an essential component of a low-cost global transition to net zero.[26] By using CCUS to decarbonise, we can create a vibrant new sector that could create huge economic opportunities in the UK. We expect to see UK industry export goods and services helping the rest of the world to decarbonise.

To enable the advancement of CCUS globally, the UK government is convening and leading international engagement on CCUS through multilateral forums and bilateral relationships. Through this, we are committed to learning from others and sharing our own experiences of deploying CCUS, as well as working with others to resolve the barriers to large scale CCUS deployment. This participation in the international community includes the following:

- The Clean Energy Ministerial (CEM) CCUS Initiative, which the UK co-leads. This aims to accelerate investment and facilitate knowledge sharing in CCUS. As co-lead, we contributed to several CCUS events at the 14th CEM in Goa, showcasing the work done to date on CCUS as well as thinking through the key challenges for scaling up the sector.
- The Zero Emissions Platform[27] (ZEP), which facilitates CCUS collaboration between countries in Europe.
- A Contracting Party member of the International Energy Agency's Greenhouse Gas Research and Development Programme (the IEAGHG), through which we collaborate with international governments and industry stakeholders to further the development of CCUS globally.
- A member of the North Sea Basin Task Force, which aims to develop common principles for developing, managing, and regulating the transport, injection, and permanent storage of CO_2 in the North Sea area. It includes members from Denmark, Flanders, France, Germany, the Netherlands, Norway, and the UK.

[23] OPITO, 'North Sea Transition Deal: Integrated People and Skills Strategy', https://www.offshoreenergypeopleandskills.co.uk/
[24] Department for Levelling Up, Housing and Communities (2021), 'Freeports', https://www.gov.uk/guidance/freeports. Freeports are special areas within the UK's borders where different economic regulations apply. Eligible businesses in Freeports enjoy a range of tax incentives and special customs measures.
[25] Department for Energy Security and Net Zero (2023), 'Carbon capture, usage and storage net zero investment roadmap', https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-net-zero-investment-roadmap
[26] Zero Emissions Platform (2018),' Role of CCUS in a below 2 degrees scenario', https://zeroemissionsplatform.eu/role-of-ccus-in-a-below-2-degrees-scenario/
[27] European Zero Emissions Technology & Innovation Platform (2023), 'The Zero Emissions Platform', https://zeroemissionsplatform.eu/

- Co-sponsors of the global Carbon Management Challenge (CMC), which will set a collective, global ambition for carbon management. Ten countries launched the CMC at the April 2023 Major Economies Forum to accelerate the scaleup of CCUS and greenhouse gas removals as necessary complements to the deployment of other zero-carbon technologies and energy efficiency. We are working alongside countries across the globe, to drive the challenge forward.

As well as working multilaterally, we work directly with several countries to exchange experiences of deploying CCUS and to unlock key investment opportunities. As a result, we are well placed to work with international partners to ease obstacles to progress and open up exciting global opportunities.

This Chapter has outlined the wide-ranging opportunities which could be afforded to the UK by the successful development of its CCUS sector. As outlined, these include unlocking economic opportunity by creating jobs and driving growth; aiding the UK in achieving its net zero goals; expediting the development of UK supply chains and improving the global development of CCUS technologies. The section which follows – Chapter Two – will lay out a pathway by which to realise these opportunities: a three-phase vision for the delivery of a self-sustaining CCUS sector.

Chapter 2:

Our Vision for Creating a UK CCUS Sector

Our vision is to make the UK a global leader in Carbon Capture Usage and Storage (CCUS), creating a self-sustaining CCUS sector that supports thousands of jobs and reduces emissions to ensure a better environment for future generations.

The vision can be broken down into four guiding principles for the CCUS sector.

Decarbonising for future generations
Aligning to a carbon budget compliant CO_2 abatement pathway.

Global Leader
Exporting the UK supply chain to help other countries build CCUS, as well as using UK CO_2 stores to sequester other countries' emissions.

Creating growth and supporting levelling up
Creating low carbon inward investment opportunities through support for a UK CCUS sector.

Building a self-sustaining CCUS sector
Increasing private sector confidence in a growing CCUS market that leads to a reduction in government support.

Making this vision a reality will require close collaboration between government and the private sector to create a new UK CCUS sector. We envisage a three phased approach to developing the sector in the UK, where the government and private sectors' respective roles change and evolve over time:

Phase 1 – Market Creation: Getting to 20 to 30 megatonnes per annum (Mtpa) CO_2 by 2030

During Phase 1, government's role is to provide the leadership necessary to create an enabling environment for the sustainable long-term deployment of CCUS. The UK aims to have four CCUS clusters by 2030, each of which will contain projects spanning multiple capture sectors (subject to the successful conclusion of negotiations). This will put us on a course to meet our net zero targets and our sectoral decarbonisation ambitions. In this phase the government has selected or intends to select clusters and capture projects through the CCUS cluster sequencing process, with government funding allocated via bilateral negotiations. The cluster approach is intended to spread the cost, as well as making the transport infrastructure more cost efficient as it can be used by a larger number of industrial emitters.[28]

We have announced up to £20 billion of funding for early deployment of CCUS, which we expect to crowd-in billions of pounds of additional private capital, creating jobs and bringing investment to our industrial heartlands. To enable private sector investment, the government has developed CCUS business models and created an economic regulatory regime through the Energy Act 2023. The framework is designed to provide the long-term certainty needed to establish and scale up CCUS across the UK, including by offering protection to investors for specified high-impact low-probability risks that the market is currently unable to bear. Our approach to the economic regulation of CO_2 transport and storage is designed to be flexible, allowing for the gradual reduction of government support as the market matures whilst recognising that, at least initially, the early CO_2 transport networks will have monopolistic characteristics which will require an independent economic regulator.

We are working with a range of regulatory bodies to enable a fit-for-purpose regulatory framework. These bodies, all of which are vital to the delivery of CCUS, include the Office of Gas and Electricity Markets (Ofgem), the North Sea Transition Authority (NSTA), the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED), the Health & Safety Executive (HSE), the Environment Agency, Natural Resources Wales and the Scottish Environment Protection Agency.

[28] This approach is recognised by the International Energy Authority, https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

Phase 2 – Market Transition: The emergence of a commercial and competitive market

In Phase 2 we envisage the emergence of a commercial and competitive market. Cost reductions due to the maturity of CO_2 transport networks, technological developments and the de-risking of CCUS through government intervention in Phase 1 – alongside market factors such as the UK Emissions Trading Scheme (UK ETS) – will mean a reduction in the need for government funding.

From 2030, there will be a need for a continued ramp up in delivery of CCUS across multiple sectors of the economy and locations in the UK. This will require us to adapt our approach, placing an emphasis on speed and scalability with a move away from the government-led cluster sequencing approach to establishing clusters in Phase 1. We anticipate CCUS will have been de-risked and, for this reason, the private sector will be able to take on the risk for new CCUS projects, something it is currently unable to do.

The regulated asset base model of economic regulation for CO_2 transport and storage will remain in place during Phase 2, providing investors with long-term revenue certainty and allowing an independent economic regulator to address market failures associated with the natural monopoly characteristics of the infrastructure. We envisage there being a new process for the allocation of economic licences for CO_2 transport and storage, and the ability to grant licences transferred to Ofgem, as provided for by the Energy Act 2023.

During this phase industry will have become accustomed to working collaboratively to align timing needs for the development of capture projects with the need to access transport and storage services. During this period storage appraisal will be accelerated. CO_2 transport and storage operators will be transparently promoting their storage capacity and industry stakeholders will have increased confidence in CO_2 storage, driving further growth across the CCUS value chain.

Where funding support for emitters is still required, there will be a transition from the current approach of awarding all carbon capture contracts based on an assessment process and then bilateral negotiations to one which is more streamlined and based on a competitive allocation process for the majority of projects. Where capture projects no longer require government subsidy and network capacity allows, government would look to become less involved in the process of allocating storage capacity, as emitters would seek to connect directly to a CO_2 transport network.

To ensure that all sectors can decarbonise, we will need to expand the CO_2 transport network, for both pipeline and non-pipeline solutions, to meet the evolving needs of users. During this period international CO_2 import networks would be enabled. We also anticipate that an approach to strategic coordination for CO_2 transport networks will be established.

Phase 3 – A self-sustaining CCUS market from 2035: Meeting net zero in 2050

By Phase 3 we envisage market conditions having emerged that allow for a self-sustaining CCUS market. We envisage a mature CCUS system incorporating different transport pathways, pipeline and non-pipeline, that can capture sufficient CO_2 to contribute to net zero whilst offering storage services to international emitters. During this phase, international companies would want to relocate to the UK to connect to a UK CCUS system. UK supply chains would assist other countries to accelerate and lower the cost of getting to net zero by helping other countries to use CCUS where necessary.

In transport and storage, we anticipate different ownership structures emerging as the market determines the most efficient model. Although we anticipate that onshore CO_2 transport networks will retain monopolistic characteristics, and therefore still be subject to economic regulation, the growth of storage capacity may lead to CO_2 stores providing competitive pricing as well as requiring adapted or reduced economic regulation.

Whilst we envisage that UK capture projects would have the potential to access multiple storage sites through multiple transport modes, we envisage a process for making new connections would be market-led and independent of government. In a market-led economy – in which value is attributed to capturing and storing carbon – the cost of capturing CO_2 would fall, allowing the CCUS sector to become self-sustaining and largely free of government support.

We have made good progress with the first phase of establishing a CCUS sector. However, transitioning from this to the second and third phase will require new policies that will see the role of government and the private sector evolving. Successful industrial cluster decarbonisation should result in clusters that are internationally competitive, enabling the decarbonisation of the supply chains and improving the value of products and services sold.[29]

The remainder of this document sets out the progress we have made with Phase 1, before outlining the steps we will be taking to transition to Phase 2. In so doing, it outlines how we plan to deliver on our long-term vision for a self-sustaining CCUS sector in the UK.

[29] UK Research and Innovation, 'Enabling net zero: a plan for UK industrial decarbonisation', p9 https://www.ukri.org/wp-content/uploads/2023/09/IUK-131023-UKRI_EnablingNetZero.pdf

Figure 3: CCUS Market Phases

	Market creation phase: until 2030	Market transition phase: 2030 – 2035	Self-sustaining market phase: 2035 onwards
Storage	Storage sites for first 4 clusters appraised and operational. Policies implemented to accelerate storage appraisal and development.	Increased confidence in CO_2 storage drives further growth across the CCUS value chain and leads to a pipeline of storage development and more stores becoming operational.	UK stores providing competitive pricing solutions and storage. Portfolio of stores is being developed to enhance competition and storage resilience.
Capture sectors	First CCUS deployment across all sectors: Industrial emitters, gas power plants, bioenergy power plants, greenhouse gas removal technologies, energy from waste, hydrogen and sustainable aviation fuels.	Continued CCUS deployment across all sectors: Industrial emitters, gas power plants, bioenergy power plants, greenhouse gas removal technologies, energy from waste, hydrogen and sustainable aviation fuels.	Continued CCUS deployment across all sectors but particular growth in GGRs: Industrial emitters, gas power plants, bioenergy power plants, greenhouse gas removal technologies, energy from waste, hydrogen and sustainable aviation fuels.
Networks	Four expanding CCUS clusters, a clear process for third party access arrangements, compatible across the Code, Licence and relevant legislation.	CCUS network expands and strategic coordination for CCUS networks.	CCUS system operational capable of meeting CCUS Net Zero contributions and importing CO2. Increasing competition and resilience in the system.
Modes of transport	Pipelines and development of non-pipeline transport (NPT) projects underway, with projects becoming eligible for allocation process.	The introduction of NPT – road, rail and shipping. International imports enabled.	Full domestic and international transport modes in practice, in conjunction with competitive storage solutions. NPT is enabling the development of a CO2 storage market.
Government Support	High levels of government support and leadership, government selects clusters with funding allocated through bilateral negotiations, competitive allocation of capture contracts commence at the end of this phase.	Reduced government support and diminishing need for government support packages and government allocates capture sector contracts competitively.	Low levels of government support as market developments significantly reduce the need for government funding and capture projects negotiate contracts with stores without government involvement.
Regulation	Energy Act, CCUS business models, and regulatory bodies establish regulatory framework for CCUS.	Ofgem allocates economic licence and emerging new economic models for transport and storage of CO_2.	Mature regulatory framework for CCUS, appropriate regulation for monopolies. Entire value chain unbundled and market determines most efficient economic models.
Economic Growth	Supply chains established with growth centred on first clusters, government funding crowds in billions of pounds of private capital, identification of early export opportunities.	As the market matures, private sector investment increases and facilitates economic benefits, such as job creation, exports and further investment in our industrial heartlands.	Supporting the creation of jobs, growth in our industrial heartlands and world leading CCUS supply chain with strong export line.
Public Perception	Increasing awareness of CCUS, key phase for public engagement.	Growing acknowledgement of the CCUS sector and support for its benefits.	Widespread public support for the CCUS sector and benefits.
Assumptions	ETS price signal High CCUS costs Market failures associated with first of a kind technology	ETS price signal and other carbon management policies CCUS costs lower Demand side policies emerge Developing low carbon products market	ETS price signal and other carbon management policies CCUS costs reduce further Demand side policies increase Mature low carbon products market

Chapter 3:

Phase One – Market Creation up to 2030

We have set the ambition to create four Carbon Capture Usage and Storage (CCUS) enabled clusters and store 20 to 30 megatonnes per annum (Mtpa) of carbon dioxide (CO_2) by 2030. In those clusters, low carbon industry, power generation and hydrogen production will be realised. New industries around greenhouse gas removal and sustainable aviation fuels will also emerge.

UK CCUS deployment is driven by specific 2030 sector ambitions, as outlined in the UK Net Zero Strategy and UK Hydrogen Strategy. The UK has a comprehensive set of ambitions, targets and commitments in place designed to drive UK CCUS deployment pre-2030 and beyond. These include:

- Bringing forward multiple additional power CCUS projects by 2030 to put us on track to decarbonise the power sector by 2035, subject to security of supply.
- Capturing 6 Mtpa of CO_2 from industry and at least 5 Mtpa of CO_2 from engineered Greenhouse Gas Removals by 2030.

Deployment of CCUS also assists in achieving several other government sector targets. Development of CCUS-enabled hydrogen supports our ambition of having up to 10 Gigawatts (GW) of low carbon hydrogen production capacity by 2030. The forthcoming sustainable aviation fuel (SAF) mandate has a target of reaching at least 10% SAF in the jet fuel mix by 2030; which will require a CCUS contribution.

CCUS projects are large-scale infrastructure projects which take many years to develop. They involve the establishment of complex stakeholder relationships and collaboration between many parties across several regulatory regimes. In this first phase of deployment of CCUS, government is providing the leadership necessary to create a sustainable CCUS sector which will deliver longer-term economic benefits for the UK.

Cluster sequencing and cluster expansion

In 2021, the government launched the CCUS cluster sequencing process: a cluster selection process which is structured into two ‘Tracks’. Subject to the conclusion of negotiations, our ambition is for Track-1 to deliver the first two CCUS clusters in the UK. The selected Track-1 clusters of HyNet and the East Coast Cluster are under negotiation. In March 2023 negotiations commenced with 8 potential capture projects within these two clusters. In the East Coast Cluster, the potential capture projects are Net Zero Teesside Power, H2Teesside and Teesside Hydrogen CO_2 Capture. In the HyNet Cluster they are Heidelberg Materials Cement Works Carbon Capture and Storage Project, Viridor Runcorn Industrial CCS, Protos Energy Recovery Facility, Buxton Lime Net Zero and Essar Energy Transition Hydrogen Production Plant. Government’s ambition is to start supporting the Track-1 CCUS clusters from the mid 2020s.

In July 2023, the government announced that the licensed stores and their respective transport and storage systems of Acorn in St Fergus, Scotland and Viking CCS project in Humber, England, were selected for Track-2 development. Our Track-2 aim is for the two additional clusters by 2030, incorporating lessons from Track-1. As outlined in the Track-2 Market Update, in early 2024, government will ask Acorn & Viking to submit plans for assessment of an 'anchor phase' of initial capture projects provisionally targeting deployment from 2028-29, subject to technical feasibility, affordability, and value for money. To provide context, government will also request that Acorn & Viking provide a provisional cluster expansion plan for a 'buildout phase' of additional network and storage expansion to enable additional projects. The anchor plans would need to be consistent with the requirement for the credible demonstration of connecting via pipeline to at least two projects for an initial phase of capture and enabling future phases of store and network expansion to enable both additional piped and non-pipeline transport (NPT) projects.

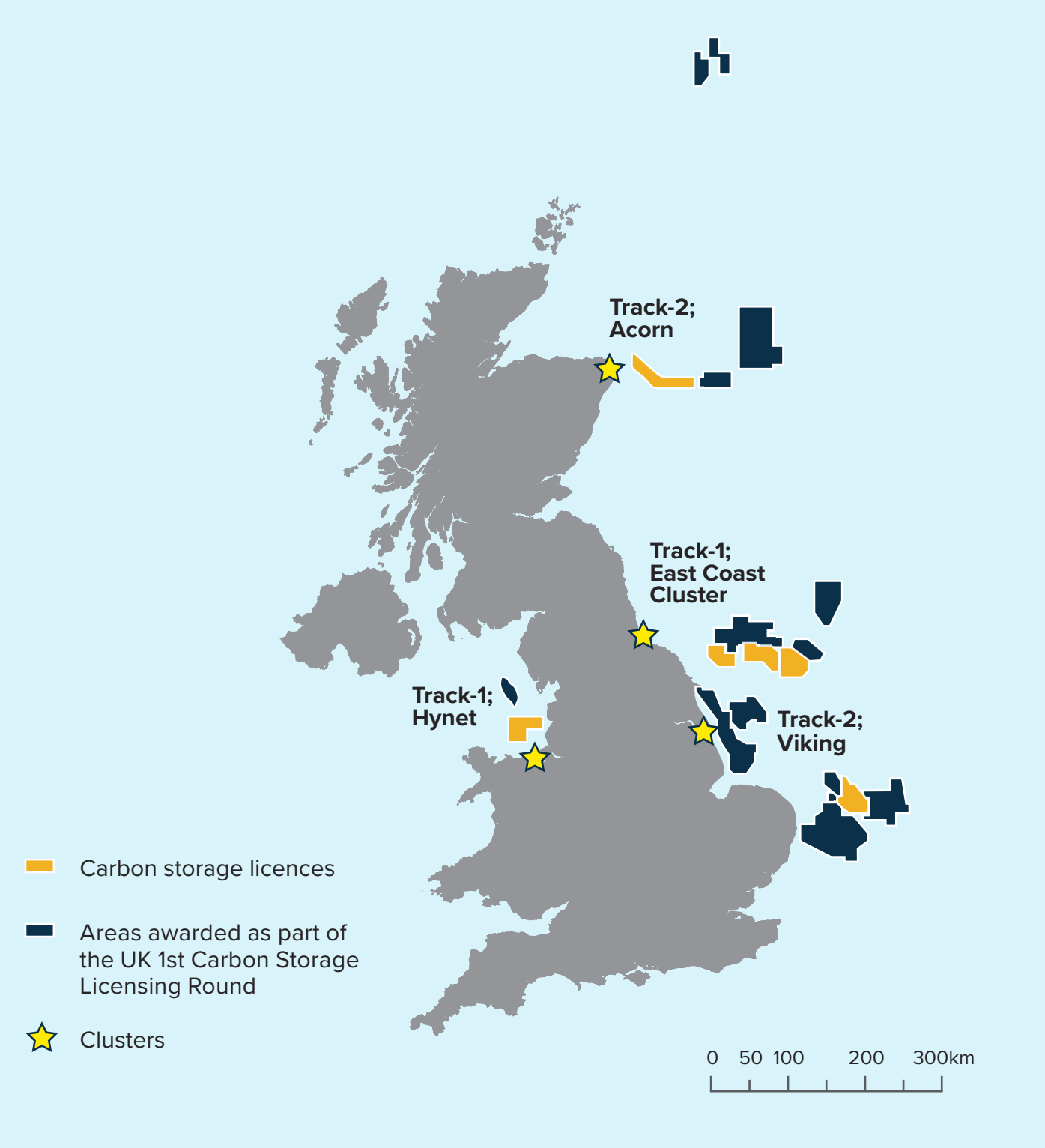
To further strengthen the Track-1 CCUS clusters we are launching a Track-1 expansion process in parallel to this document. This expansion process is initially designed to utilise further storage capacity within the HyNet cluster and will be developed to support further expansion of the East Coast Cluster in due course. By opening the Track-1 Expansion HyNet Process application window, full CO_2 transport network capacity is expected to be reached in 2030. Next to industry, power and low carbon hydrogen emitters greenhouse gas removal companies are also eligible to apply to Track-1 expansion. Users who are not requesting direct government CCUS support are also eligible to apply. These 'unsupported users' show that the UK is serious about transitioning to a self-sustaining CCUS market.

Organising for delivery

The successful collaboration of many parties across several regulatory regimes, and between the public and private sectors, will be critical to the success of enabling a sustainable CCUS sector. That is why as part of our delivery model we have established government-led Cluster Working Groups made up of government, capture projects, CO_2 transport and storage companies and regulatory organisations such as the North Sea Transition Authority (NSTA), the Office of Gas and Electricity Markets (Ofgem), the Health and Safety Executive and the Environment Agency. The aim of these working groups is to drive the development of collaborative solutions to the challenges that arise in delivering infrastructure projects of this complexity.

In developing our model to enable the delivery of CCUS and build the structures necessary to achieve our carbon budget targets, we have drawn on the expertise of the UK's Infrastructure Projects Authority (IPA). The IPA is the government's centre of expertise for infrastructure and major projects delivery. We are drawing on the IPA's expertise as we recognise the importance of CCUS in delivering government's ambitions and the delivery complexity associated with the deployment of CCUS.

Figure 4: CCUS Track-1 and Track-2 Process



Case study – Acorn: the catalyst for industrial decarbonisation in Scotland and beyond

Acorn is a joint venture between Acorn Partners Storegga, Shell UK, Harbour Energy and North Sea Midstream Partners.

Acorn proposes to play a major role in helping the UK and Scotland meet their net zero commitments, allowing industry to decarbonise while protecting and creating jobs. Re-purposed oil and gas infrastructure will be used to transport captured CO_2 emissions to permanent geological storage 2.5 kilometres under the North Seabed. The CO_2 will come from the Scottish Cluster, a collection of industrial, power and hydrogen businesses in Scotland's Central Belt and North East. Acorn is also working to develop a blue hydrogen production facility at the St Fergus gas terminal, while its proximity to Peterhead Port could support broader domestic and international decarbonisation, with CO_2 being shipped into a dedicated terminal before onward transfer to the Acorn storage facility.

In July 2023, Acorn was selected by the UK government as one of two transportation and storage systems best-placed to deliver the government's Track-2 objectives. In Track-1 Acorn is also a reserve cluster. As one of the four CCUS clusters, Acorn is expected to make a significant contribution to reach the UK's target of 20 to 30 Mt CO_2 per annum by 2030 and part of the 2 new CCUS clusters that together have the credible potential to store at least 10 Mtpa of CO_2 by 2030 through a range of carbon capture projects.

Creating an economic regulatory framework for CCUS

Lessons have been learned from previous attempts to develop CCUS in the UK, including the issues of risk allocation that affect the deployment of CCUS in clusters. We have overcome this issue through the development of targeted commercial and economic regulatory frameworks. The frameworks have been developed through extensive engagement and collaboration with representatives from the many sectors and industries for whom CCUS is critical to achieve their decarbonisation objectives.

These regulatory frameworks are designed to address what are known as "cross-chain risks". These risks are defined as risks where the acts or omissions of one party may cause a cost or negative impact to another. It is appropriate (subject to subsidy control and value for money) for government to play a role in mitigating some of these risks due to the nascent stage of the sector.

As CO_2 transport and storage networks are likely to be operated as natural regional monopolies, encompassing a range of different network users and emitters, operating under different commercial models, a framework of economic regulation is appropriate to protect network users from anti-competitive behaviours, including monopolistic pricing. The Energy Act 2023 establishes the legislative framework for the economic regulation of CO_2 transport and storage, with Ofgem as the independent economic regulator. This is described in more detail in the Annex. The Energy Act also establishes the primary legislative framework for the Industrial Carbon Capture, Greenhouse Gas Removals and Low Carbon Hydrogen Production business models. The framework is designed to:

- attract private finance,
- remove market barriers to investment, and
- provide long-term revenue certainty to establish and scale up these industries across the UK.

The business models are tailored to different CCUS sectors and form the groundwork for the eventual commercialisation of the new industries, as they are designed to reduce government support over time. The business models include:

- the Industrial Carbon Capture (ICC) and waste business models to de-risk deployment and provide ongoing revenue support for industrial and waste management emitters to decarbonise;
- the Hydrogen Production Business Model to incentivise investment in new low carbon hydrogen production and encourage users to switch to low carbon hydrogen by making it a price competitive decarbonisation option[30]
- the Dispatchable Power Agreement (DPA) contractual framework for power CCUS which will enable the deployment of flexible low carbon power to complement renewable electricity and nuclear power;
- the power Bioenergy with CCS (power BECCS) business model, which will be a dual Contract for Difference rewarding negative emissions and the low carbon electricity co-product; and

[30] Department for Business, Energy & Industrial Strategy (2021), 'UK hydrogen strategy', https://www.gov.uk/government/publications/uk-hydrogen-strategy

- the Greenhouse Gas Removals (GGRs) business model which will reward negative emissions to attract private investment and accelerate commercial deployment of a range of GGR technologies.[31]

The Energy Act 2023 sets out the powers and duties given to Ofgem as the economic regulator for CO_2 transport and storage and makes provision for government financial support. The support packages developed are described in more detail in the Annex. The Act allows for a new transport and storage economic licence allocation process to be established, once the cluster sequencing process is complete. At this point it is expected that the responsibility for granting transport and storage economic licences for CO_2 network operators will pass to Ofgem, provided the market is sufficiently mature and subject to the necessary secondary legislation being in place. The Energy Act 2023 also allows for different types of economic licences for CO_2 transport and storage to be created as the market develops and competition emerges.

Government is also working in close cooperation with CCUS delivery partners to develop a clear and effective CCS Network Code. This sets out the commercial, operational and technical arrangements for use and growth of the CO_2 transport and storage system. Following its implementation, the CCS Network Code can be further developed by industry as the CO_2 transport networks mature. The code includes governance arrangements that set out roles, responsibilities and processes around modification, including for non-parties who have a significant/material interest in its future shape and function. Third party access to transport and storage infrastructure will be governed by provisions in the economic licence and CCS Network Code. A legislative basis for access rights will be provided where needed by the Access to Infrastructure Regulations, which will have been reviewed to ensure they remain fit for purpose for CO_2 transport and storage infrastructure into the future.

Chapter 3 has laid out the features of the first phase of development for the UK CCUS sector: the market creation phase. As noted, government intends to establish four CCUS clusters during this first phase. It outlines government's intention to collaborate closely with industry and regulatory bodies to deliver this phase and the legislative framework for the regulation of CO_2 transport and storage. The section which follows – chapter 4 – will set out government's vision for Phase 2 of the development of the UK CCUS sector: the market transition phase.

[31] Department for Business, Energy & Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', https://www.gov.uk/government/publications/net-zero-strategy

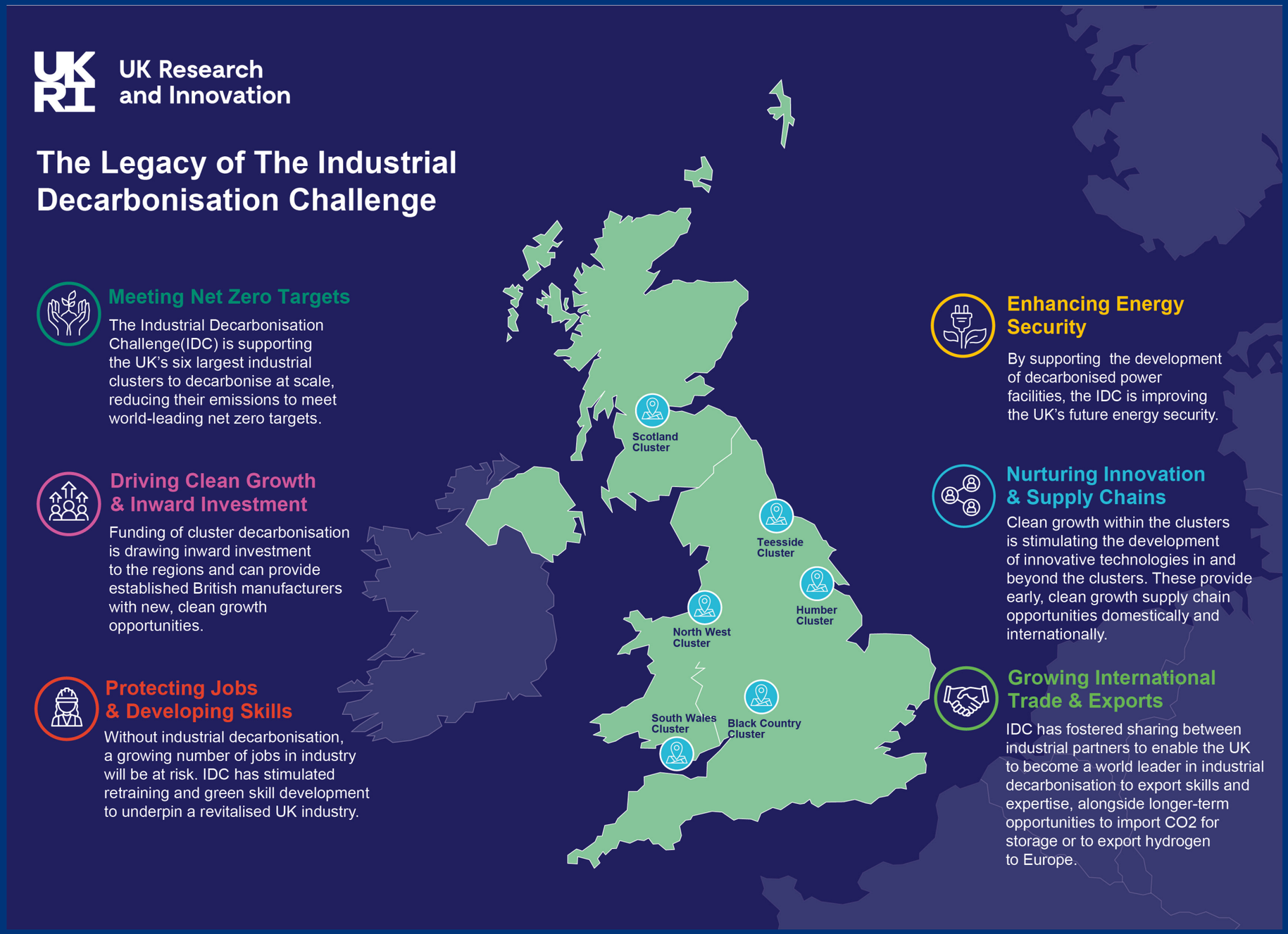
What is the Industrial Decarbonisation Challenge?

The Industrial Decarbonisation Challenge (IDC) is a £210 million programme, matched by £261 million from industry, and delivered by UK Research and Innovation (UKRI). The challenge is comprised of three strands:

(1) Deployment projects: The deployment projects have produced the engineering designs, simulations, commercial arrangements and impact assessments required to underpin the infrastructure needed to enable the deep decarbonisation of key UK industrial clusters. The projects comprise a mix of onshore projects that include pipework, gas compression, hydrogen production, gas storage and carbon capture, and offshore projects that include offshore storage of CO_2 and offshore pipework.

(2) Cluster Plan projects: Cluster Plans have been developed in the North West, Humber, Teesside, the Black Country, Scotland and South Wales, setting out how Net Zero targets can be achieved. These plans have also contributed to the development of a UK Wide Cluster Plan, which sets out how the UK can harness the power of the industrial clusters and drive the next phase of emissions reductions.

(3) Industrial Decarbonisation Research and Innovation Centre (IDRIC): IDRIC has over 60 research projects addressing key challenges / pathways for industrial decarbonisation. These projects support technology development and the creation of a positive enabling environment for industrial transition in the UK.



The IDC projects have provided the genesis for the development of the CCUS industry in the UK by readying the technology and path to net zero for the UK's industrial clusters. In addition to this, supply chains, engagement with the local cluster communities and understanding of the skills needed to support the CCUS industry have grown through the development of the projects. Crucially, the IDC has encouraged and facilitated knowledge sharing, laying the foundation for collaboration both within and between clusters that is required to accelerate the cost-effective development of the CCUS industry.

Chapter 4:

Phase Two – Market Transition

The emergence of a commercial and competitive market

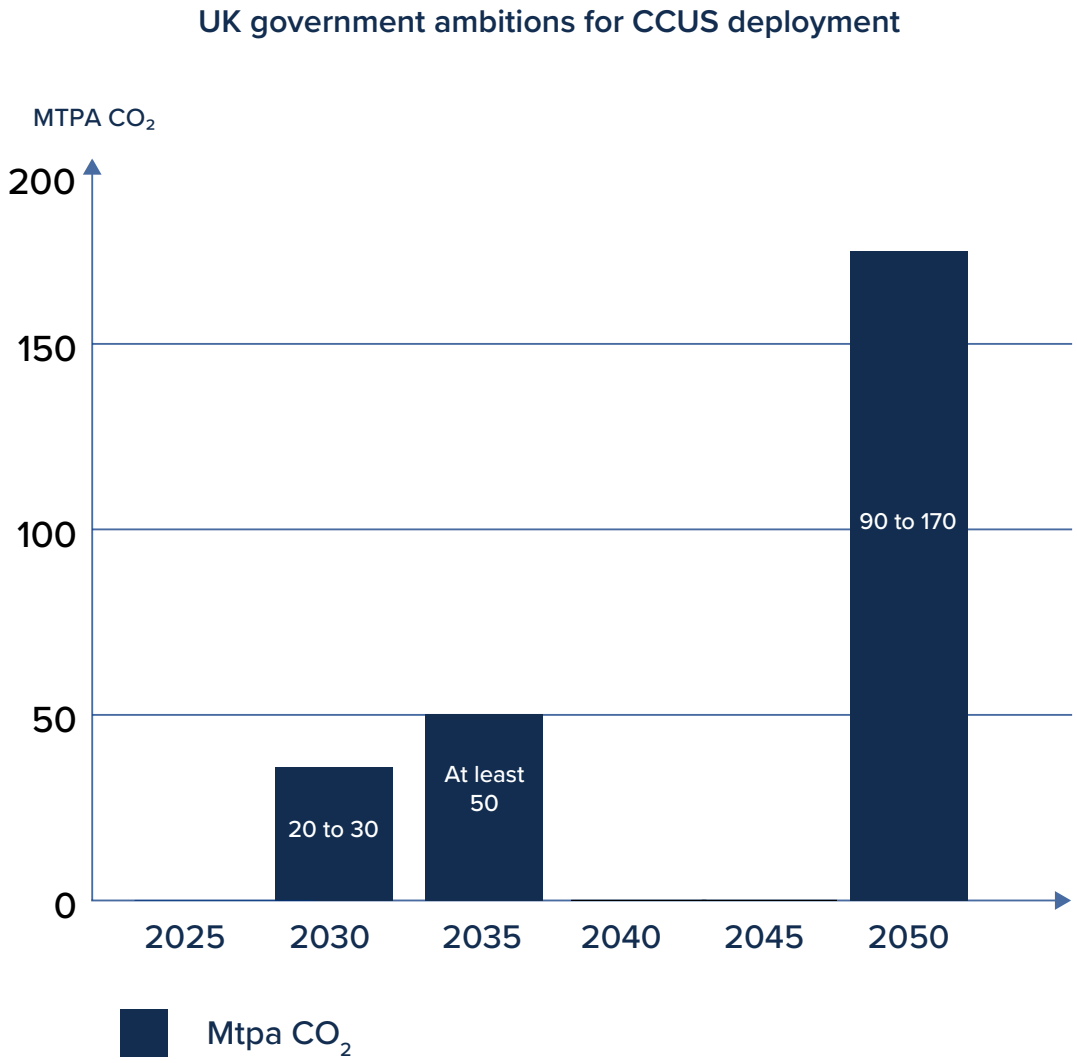
The government's ambition is to establish four CCUS clusters across the UK by 2030, with projects delivered across a range of sectors. Beyond 2030, a significant ramp up in deployment of CCUS will be required to further support individual sector decarbonisation routes and deliver the expected contribution to Carbon Budget 6. By the mid 2030s, the amount of CO_2 annually stored may need to increase to at least 50 megatonnes per annum (Mtpa).[32] To achieve this, it is likely that the CCUS sector will need to increase the annual amount of CO_2 stored by at least 6 Mtpa from 2031. Delivering this increase will require an evolving approach, placing emphasis on speed and scalability with a move away from the approach used to establish the first four clusters – subject to affordability and value for money. Less government intervention will be required to enable the establishment of new CO_2 transport networks and network expansion, meaning that industry will have to work collaboratively to align the timing between the capture projects and transport and storage networks.

During the market transition period, international CO_2 import networks will be enabled and storage appraisal will be accelerated. In this period, the market conditions will have changed due to growing confidence in CCUS technology and the de-risking of CCUS through existing government intervention in the first four clusters. This, together with developments in areas such as UK Emissions Trading Scheme (ETS) and potential mechanisms to mitigate carbon leakage, will mean a greater role for the private sector and a reduction in the need for government funding and support. Where funding support for capture projects is still required, there will be a transition to a process based on competitive allocation.

Taken together, these changes will enable the required expansion of the sector, provide support to individual sectors' decarbonisation pathways and make significant progress in establishing a CCUS sector largely free of government support. Developing and embedding these changes in the CCUS market will be a multi-year, multi-stage process; further work is needed by government and industry to take this forward.

[32] Powering Up Britain: Net Zero Growth Plan (2023), https://www.gov.uk/government/publications/powering-up-britain

Figure 5: UK Government CCUS Roll Out Range of Ambitions



We anticipate that the key developments required to deliver this more market-led approach are:

- **Establishment of a new process for the allocation of economic licences for CO_2 transport and storage**, and the ability to grant licences transferred to Ofgem, as provided for by the Energy Act 2023. Ofgem will carry out its functions in relation to the regulation of CO_2 transport and storage in line with its principal objectives and statutory duties established in the Energy Act. This will allow for the efficient and economical expansion of CO_2 transport networks, ensuring the interests of both current and future users of the networks are protected, and having regard to statutory carbon budgets and targets across the UK.
- **Capture contracts to be allocated through a more competitive process** to accelerate the pace and scale of deployment and incentivise cost reduction. Regular scheduled allocation rounds, with the initial round expected around 2027.

- Familiarisation with onshore and offshore CO_2 transport networks and increased competition in segments of the CO_2 transport and storage chain will allow **new economic models for transport and storage to emerge**, resulting in the evolution of the economic regulation of CO_2 transport and storage.
- **Existing business models for transport and storage and for carbon capture projects will continue to evolve** to reflect a more market-led approach and the increased role that the private sector will play in managing cross chain risks.
- **Increasingly streamlined leasing, licensing and permitting processes across regulatory bodies will be developed, with the aim of accelerating subsurface storage appraisal**. This will support the pace and scale of carbon storage appraisal required.
- **Non-pipeline transport (NPT) will be operational** both onshore and offshore, **linking emission sources with permanent geological storage**. The government has been engaging closely with industry on the potential options for NPT and how these might be integrated into the wider CCUS landscape. To support industry in their work, the government will shortly publish a call for evidence on how it envisages NPT to be delivered in the UK. We anticipate that NPT projects will be eligible for selection as capture projects from 2025 onwards.
- **Consideration of the strategic direction for CO_2 transport networks**, including developing an understanding of the degree of strategic co-ordination needed and any potential role for the Future System Operator.
- Enabling **the import of CO_2**, to allow the UK to benefit from its strategic advantages, helping to lower costs to UK CO_2 transport network users and stimulating growth of Transport & Storage (T&S) infrastructure, which in turn will provide critical support for meeting our domestic CO_2 storage targets. The government will also explore the potential role of CO_2 exports in providing increased resilience in the UK CCUS sector.
- **Increasing market maturity will reduce the need for government support**. Growing confidence in the T&S business means that the need for support packages currently offered as part of the cluster sequencing process will diminish as the market matures and the availability and depth of CCUS commercial insurance products increases. All stakeholders have a common interest in establishing a successful merchant market model for the acquisition of new customers and network expansion as rapidly as possible.
- **Innovation and cost reductions** facilitated by the development of the global CCUS sector, the development of UK ETS and increasing ability for costs to be recovered by businesses, **will reduce the amount of government/consumer funding required for capture projects**. The government will also continue to explore policy options (such as carbon take back obligations or carbon storage obligations) to increase the investability of CCUS and reduce the need for government support.
- **Review of the existing regulations regarding third party access to CO_2 transport and storage infrastructure** to ensure they are fit for purpose.

Development of CCUS market frameworks

The government will launch a consultation in 2024 on the future market frameworks for CCUS. The intention will be to develop a scalable model to efficiently accelerate deployment whilst driving cost reduction and reducing the degree of government support. This consultation will include proposals on introducing enhanced competitive allocation for CCUS and how this will interact with the wider policy landscape such as energy, industry, hydrogen, negative emissions and low carbon product markets.

It is anticipated that the outcome of this work will enable us to move to a system of regular allocation rounds to enable operations of new stores and their capture projects from the early 2030s, but the decision on this, and the accompanying detailed policy required, will be subject to the aforementioned consultation. How expansion of existing stores will interact with this work will also need to be determined. This could mean a mechanism for allocating capture contracts being in place from around 2027.

Alongside a consultation on allocating capture contracts, a process for the future allocation of transport and storage economic licences would need to be developed, and the ability to grant licences transferred to Ofgem at the appropriate time, as provided for in the Energy Act 2023. This process would need to consider the relationship between the submission of a licence application and the timing of capture contract allocation, as well as the award of both capture contracts and the economic licence.

To be consistent with a Carbon Budget 6 timeline, a process for applications for new economic licences for transport and storage may need to be in place from 2025/6, so that CO_2 transport networks can be sufficiently designed to run an allocation round for prospective capture projects. This would mean that the future market design will consider how best to ensure projects are sufficiently mature from both a transport and storage, and capture project perspective. For example, it may be that to be able to participate in a competitive allocation process, capture projects would need to be sufficiently progressed with their engineering studies and planning and consenting. Consideration will also need to be given on how to align the allocation of new economic licences for transport and storage with development of new storage facilities under the North Sea Transition Authority CO_2 storage licensing regime. The process will also consider the coordination needed between the CO_2 transport networks and capture projects initially selected for designs to be finalised, investment decisions taken and construction to commence.

Any implemented competitive allocation process will need to be specifically designed for the complex and interconnected nature of the developing UK CCUS industry. It will need to address how different projects, sectors and non-pipeline transport projects may participate given their differences, any interactions with existing allocation processes and markets, how allocation processes should reflect sectoral decarbonisation targets and how to provide sufficient visibility and confidence to enable businesses to invest in developing their projects. The process will also need to consider how prospective transport and storage companies will have sufficient visibility on the supply of CO_2.

The new market framework is likely to require further legislation, establishment of an allocation body and setting up of a new delivery framework to effectively enable a series of regular allocation rounds. Business models for both capture projects and CO_2 transport and storage (which could include different models for onshore transport, offshore transport and storage) will also need to adapt.

Cost and Funding

The government has announced up to £20 billion for the early deployment of CCUS in the UK and aims to establish four clusters by 2030. As we move beyond those CCUS clusters, it is the government's view that the level of direct government funding will be significantly reduced and that the 2030s will see a significant shift to a CCUS sector largely free of government support. This transition will be driven by investor confidence in the sector; cost reduction driven by technical and market innovations; operational delivery; developments in the UK Emissions Trading Scheme (ETS) market; the availability of commercial insurance products and other government policies that impact CCUS investability.

The move to a more market-led approach will support this shift, with the allocation of capture contracts driving cost reductions and increasing the visibility of CO_2 supply for Transport and Storage Companies (T&SCos). Industry is expected to play a major role by identifying and adopting new and innovative low-cost solutions across the value chain.

Increasing investor confidence in the sector

In setting out the approach to establishing a CCUS sector, the government recognises that potential transport and storage company operators require confidence in both the supply of CO_2 from users and the ability to manage potential liabilities associated with a leak of CO_2 from the geological store. The Revenue Support Agreement[33] and Government Support Package[34] are bespoke contractual arrangements currently being offered to the Track-1 clusters, to protect investors and facilitate investment in first of a kind transport and storage infrastructure. The need for such arrangements will be monitored and kept under review as the sector develops, but there is an expectation that market based products will be developed to manage these risks.

In the coming years, the ambition is that four clusters will, subject to the successful conclusion of negotiations, progress to construction and operations, demonstrating the viability of the transport and storage business model. There has also been – via the development of cluster decarbonisation plans and the government's Power, Hydrogen and Greenhouse Gas Removal policies – increasing certainty in the supply of CO_2 for potential transport and storage licence holders. Additional policies outlined in this document – including competitive allocation of capture contracts, non-pipeline transport models and enablement of CO_2 imports – will further increase investor confidence in the sector.

Taken together, these developments will provide sufficient commercial certainty for potential investors. As a result, it is the government's view that the Revenue Support Agreement will increasingly no longer be required during this market transition phase. It is also expected that the scope of any Government Support Package will be focussed on managing the risk of CO_2 leakage from the geological store where commercial insurance is unavailable.

[33] The Revenue Support Agreement is a mechanism to mitigate demand-related revenue risks to transport and storage companies. It is designed to improve investability in the initial development of the CCUS sector, where there may be a lack of visibility and/or confidence in the supply of CO_2.

[34] The Government Support Package covers certain high impact, but low probability, risks beyond those that can be managed by operation of the CCUS Economic Regulatory Regime, which the Transport & Storage Companies cannot take or cannot price at an efficient level that is good value for money for UK taxpayers or consumers.

Reducing costs for CCUS

As the CCUS market develops, both in the UK and globally, it is expected that the cost of capturing, transporting and storing a tonne of CO_2 (£/tCO_2) will reduce. This is in line with the experience of many industries that have gone through a rapid expansion and is supported by the more than £346 million of UK government investment for research, development and demonstration CCUS projects from 2004 to 2021. It is expected that part of the cost reduction will come from decreasing financing costs as confidence in the investability of the CCUS sector increases. Additional cost reduction will be driven by technical and market innovations across the full value chain, with some example areas being:

- The development of next generation capture technologies with lower energy penalties.
- Advances in compression and liquification techniques.
- The development of modularised capture plants to reduce upfront capex and ongoing opex costs.
- Service market offerings, including capture as a service, to reduce ongoing opex costs.
- Better utilisation of CO_2 transport networks.

The government expects the UK CCUS industry to continue to lead the research, development, demonstration and adoption of these technical and market innovations, with targeted innovation support continuing through appropriate government support.

In 2024 we will establish an industry working group on the identification and timely adoption of cost reduction opportunities.

The introduction of a market-led allocation of capture projects will promote the adoption of lower cost technologies and approaches to CO_2 capture, reducing its cost. The approval of transport and storage economic licences and future network expansions will also drive the adoption of lower cost solutions and optimal use of CO_2 transport networks, reducing the overall cost of transporting and storing CO_2. In addition, we expect the development of a CO_2 import market will reduce costs for UK users of the CO_2 transport networks and diminish the need for government support. Taken together, these changes mean that the overall level of government support will be significantly lower in the 2030s.

Research, Development & Demonstration (RD&D)

The UK government facilitates research, development & demonstration into CCUS through offering several opportunities, such as up to £210 million via the Industrial Strategy Challenge Fund; up to £115 million from the £1billion Net Zero Innovation Portfolio (NZIP) to develop CCUS and carbon removal technologies in the UK; up to £18 billion private financial capacity available from UK Infrastructure Bank for sectors including Hydrogen/CCUS, and £176 million of funding for sustainable aviation fuels which has been allocated through a series of grant funding schemes.

Development of other policies to increase CCUS investability

Investment in the sector has, to date, been primarily supported by the ETS and the CCUS business models, regulatory framework and financial support programmes established by government. As the CCUS market develops, the government expects a number of policies to play an increasingly important role in supporting CCUS investment, with a corresponding reduction in the direct CCUS support required. It also expects that industry will actively work with government to develop additional solutions to increase the investability in CCUS.

The continuing evolution of the ETS market will be a key driver of investability in CCUS. In its recent report[35] on developing the UK Emissions Trading Scheme, the government reaffirmed that net zero sits at the heart of its plans, with the scheme acting as a foundation for a thriving, decarbonised economy through 2050 and beyond. As part of this the UK ETS Authority announced that:

- From 2024, the UK ETS cap will be aligned with the net zero trajectory.
- The UK ETS will be expanded to domestic maritime emissions in 2026; energy from waste and waste incineration in 2028; and to allow for the transportation of CO_2 through non-pipeline transport.
- The UK ETS Authority will consult further, including on future markets policy and inclusion of greenhouse gas removal technologies.

Policies to address carbon leakage will support industry to invest in and realise decarbonisation now and in the future, improving the investment case for carbon capture. The government consulted on 'Addressing carbon leakage risk to support decarbonisation' earlier in 2023 and received over 160 responses. This exploratory consultation sought views and evidence from a broad range of stakeholders on potential policies to manage future carbon leakage risk including a carbon border adjustment mechanism (CBAM), mandatory product standards (MPS), and other policy measures to help grow the market for low carbon products, as well as embodied emissions reporting that could support the implementation of these policies.

On 18 December 2023, the government published its response to the consultation, announcing that it will:

- Implement a CBAM by 2027, applying a charge on the carbon emissions embodied in imports from the following sectors: aluminium, cement, ceramics, fertiliser, glass, hydrogen, iron and steel.
- Work with industry to establish voluntary product standards that businesses could choose to adopt to help promote their low carbon products to customers.
- Develop an embodied emissions reporting framework that could serve future carbon leakage and decarbonisation policies.

These measures will be subject to further consultation in 2024.

[35] Department for Business, Energy & Industrial Strategy; Welsh Government; The Scottish Government; Department of Agriculture, Environment and Rural Affairs (Northern Ireland) (2022), 'Developing the UK Emissions Trading Scheme', https://www.gov.uk/government/consultations/developing-the-uk-emissions-trading-scheme-uk-ets

The government is working with the CCUS Council[36] to explore the impact of introducing a Carbon Take Back Obligation or Carbon Storage Obligation on companies that extract fossil fuels. If such a policy was introduced, it could provide support for investment in the CCUS sector. This work is at an early stage and we will continue to seek to understand how wider policies such as this may support the transition to a sustainable CCUS sector.

Specific policies may also be introduced for individual sectors that support decarbonisation and the use of CCUS. For example, the government is introducing a mandate on fuel suppliers to supply sustainable aviation fuel (SAF) from 2025. Fuel suppliers will be awarded tradable certificates, with a cash value, for the supply of SAF. The government's consultation in spring 2023 on how the mandate will operate proposed that certificates will be awarded proportionately to the greenhouse gas (GHG) emissions of their fuels, with the greenest fuels receiving the greatest awards. The consultation included a specific question on whether GHG reductions from CCUS be rewarded under the SAF mandate and whether this reward should extend to net negative emissions. The inclusion of CCUS in SAF production could allow emission savings to be maximised, with the potential of producing negative emissions. The government response to the consultation will confirm the final design of the SAF mandate, including how CCUS is treated under the mandate.

The production process of low carbon fuels for other transport modes, like road and maritime, may be able to utilise CCUS. We will conduct further work to establish the role of CCUS in these applications and how similar incentives for the use of CCUS can be attributed to these fuels in both existing schemes like the Renewable Transport Fuel Obligation and any future schemes for modes beyond road and aviation.

It is expected that advances in the policy areas outlined will reduce the need for direct government support though CCUS capture contracts.

[36] UK Government (2023), 'CCUS Council', https://www.gov.uk/government/groups/ccus-council

CO_2 Transport Networks

This section sets out our vision for the development and deployment of CO_2 transport networks, outlining both the challenges and opportunities. To achieve our decarbonisation targets, we will need to increase the amount of CO_2 stored by at least 6 megatonnes per annum (Mtpa) from 2031 to 2035. To deliver these ambitions, we will need to ramp up the UK's CO_2 transport infrastructure, linking emissions to permanent geological storage.

A reliable CO_2 transport network is necessary to enable the development of flexible, low-carbon power, decarbonised industrial sectors and to unlock large volumes of low carbon hydrogen and CO_2 removals. As a result, there may be advantages in considering how greater strategic coordination of the formation of such networks can enable efficient and resilient networks.

As CO_2 transport networks expand, there may be strategic benefit to a more coordinated, whole-system approach that is responsive both to the needs of industry and to the local communities in which these networks will be located.

The development of CO_2 transport networks will need to consider the access requirements of sites located away from CCUS clusters currently being developed. We will undertake a review of the existing regulations regarding third party access to transport and storage infrastructure to ensure that they remain fit for purpose.

The creation and development of CCUS transport networks will represent both a significant challenge and an infrastructural opportunity for the UK. We consider that there are strategic advantages to the creation and operation of such networks. In particular, the development of CO_2 transport networks could:

- Build resilience and flexibility into the sequestration of CO_2. With multiple potential ways for CO_2 to enter the CO_2 transport networks (road, rail, ship, pipeline) and to exit into permanent geological storage, these networks could reduce constraints, potentially offering greater 'security of sequestration' for the UK; and
- Reduce the overall costs of CCUS as individual transport providers compete on price. In doing so, such networks could offer potential economies of scale, with lower costs arising from better utilisation and the adoption of technology and market innovations.

Informed by the National Infrastructure Commission's 'Second National Infrastructure Assessment,[37] we will look to deepen and broaden our understanding of the evolution of CO_2 transport networks in 2024. Working with industry and wider stakeholders, we will develop a greater understanding of network costs. We will also work with industry and wider stakeholders to consider the strategic direction for CCUS transport networks, including developing an understanding of the degree of strategic co-ordination needed and any potential role for the Future System Operator.

[37] National Infrastructure Commission (2023), 'Second National Infrastructure Assessment', https://nic.org.uk/studies-reports/national-infrastructure-assessment/second-nia/

We will also consider how a CCUS Strategy and Policy Statement may inform the development of CO_2 transport networks and help facilitate the investment needed to support their growth and development. A CCUS Strategy and Policy Statement would provide an articulation of the government's strategic priorities and desired policy outcomes for CCUS. The Office of Gas and Electricity Markets (Ofgem) would be required to consider the strategic priorities set out in the statement when executing its CCUS-related functions, carrying out these functions in the manner best calculated to achieve the policy outcomes.

Strategic Coordination and the role of Government

During this first phase of deployment of CCUS, government's role is to provide the leadership and coordination necessary to create an enabling environment for the sustainable long-term deployment of CCUS. This includes the establishment of the cluster sequencing process to develop the first four clusters and the wider economic and business model framework.

The development of national CO_2 transport networks will be a complex and multi-dimensional undertaking. It will involve co-ordinating the transportation of the various sources of domestic CO_2 emissions across the UK with the international importation of CO_2 and is likely to require wider, more strategic, linkages between these CO_2 transport networks and other decarbonised low carbon transport networks (such as hydrogen). A continued role for government in relation to strategic coordination could lead to more efficient infrastructure build-out at the right pace, location and scale, resulting in greater investor confidence and ensuring that decarbonisation goals are met.

The development of CO_2 transport networks in the UK and their integration into the wider energy infrastructure system, however, is not something that can, or should, be resolved by government alone. The development of CO_2 transport networks will need to be a strategic and collaborative endeavour; it will require a deep and lasting partnership between government, transport providers, potential clusters, projects in dispersed sites and the UK CCUS supply chain, to harness the potential of this significant infrastructural opportunity. It will also need to feed into and complement the UK's first ever spatial plan for energy infrastructure.

Capture projects and transport providers will need to collaborate with the UK CCUS supply chain to ensure long-term success. Government will need to collaborate with industry to solve strategic planning and network issues.

The extent to which the build-out of CO_2 transport networks should be strategically planned against defined criteria and timelines remains a live issue. Government takes an open view, at this stage, on this point.

We believe there may be advantages to a more co-ordinated, whole-system, strategic approach to CO_2 transport networks. In particular, we expect such coordination could:

- Enable a more efficient build-out of CO_2 transport networks, correctly sized, located in the right place at the right time and sensitive to the needs and aspirations of local communities;
- Seek to understand the potential benefits and trade-offs of building ahead of need and anticipatory investments.

As we decarbonise our energy system it will become ever more integrated. The development of CO_2 transport networks will need to be considered alongside the development of other energy networks. A whole system approach to the establishment of CO_2 transport networks will need to consider

maximising decarbonisation, system resilience, value for money and the needs of the different users wanting to connect to CO_2 transport networks. CO_2 network operators will have an important role in this.

In relation to the development of the initial CO_2 transport networks, the establishment of a CCS Network Code will form a key component of the strategic framework being developed for CO_2 transport and storage. There will be a single CCS Network Code, rather than each T&S Network having its own network code with different terms. A single Code will allow for expedient and resilient development and could facilitate growth (as it is possible that some clusters may be interconnected in the future) and inter-connectivity, enabling growth in non-pipeline transport (NPT) options.

Non-pipeline transport

There will be a requirement for multiple forms of non-pipeline CO_2 transport, which will enable flexible and open access CO_2 transport networks. Multiple forms of NPT may, however, present challenges in dealing with multiple emitters and varying CO_2 specifications. Developing multi-modal CO_2 transport networks will involve the development of mechanisms to manage cross-chain liability issues across the network chain.

While it is not possible to determine how and in what ways each of the transport options will be utilised in the 2030s, we expect to see the UK deploying both pipeline and non-pipeline forms of transport. The types of CCUS transport are outlined in the table below:

Figure 6: CCUS Transportation Types

Examples of CCUS transportation	Narrative
New Pipeline	Pipeline constructed and operated specifically to transport CO_2 from emitters to permanent geological storage.
Re-purposed pipeline	A transport option based upon the reuse of existing or previously decommissioned gas pipelines. As with new pipelines, its purpose is to transport CO_2 from emission sources to permanent geological storage.
Shipping	Capable of carrying significant volumes of CO_2 over long distances. This form of transport would require additional infrastructure.
Rail	Transporting CO_2 through existing and future rail networks. This proposed solution may be optimal for low CO_2 volumes carried over 'medium' distances.
Road	Under this option CO_2 would be transported using existing and future road networks. Likely to be best suited to the transport of low CO_2 volumes over relatively short distances.

To date, the government has focused on establishing CCUS in the UK using clusters which seek to transport CO_2 via pipeline from capture projects to stores. However, as around half of industrial emissions are outside of the main industrial clusters, NPT options will be required to help decarbonise those emitters which are not able to use pipeline transportation (because they are in dispersed areas of the UK, or the cluster they are connected to does not have a nearby offshore storage site). NPT could also help improve store resilience and transport future international CO_2.

The government has been engaging closely with industry on the potential options for NPT and how these might be integrated into the wider CCUS landscape that the government is establishing. The government is encouraged to see that certain sections of the industry are coming together to develop potential NPT projects, which could act as the first projects deploying NPT in the UK. These projects are bringing together the necessary expertise from across the private sector to refine their plans and create credible projects for the capture and transport of CO_2.

To support industry in their work and provide greater clarity on the government's position regarding NPT deployment, the government will shortly publish its initial proposals on how it envisages NPT being delivered in the UK. This will likely be the first in a series of publications as we look to work with industry and other stakeholders to establish NPT in a timeframe consistent with the government's wider CCUS strategy.

Alongside this, a lack of clarity on the timeframe for the deployment of NPT infrastructure has been identified as a key blocker for securing the necessary investment to progress these projects. The government is keen to provide this clarity as soon as possible to allow projects to progress. However, there is significant work that will need to be done to facilitate the deployment of NPT in the UK, in addition to the development of the government's NPT policy itself. This includes amendments to the existing Business Models to support the financing and appropriate risk allocation of NPT and amendments to the CCS Network Code to support the operational integration of NPT into the wider UK network. We anticipate NPT projects being eligible to apply for emitter selection processes that open from 2025 onwards, to help meet the stated ambitions. Further detail on this will be provided in due course.

Access to CO_2 Transport Networks

The ability to access a CO_2 transport network to sequester captured CO_2 is essential for emitters. Their confidence in investing to develop projects will depend on whether they have confidence in being able to access a network.

CO_2 transport network operators are subject to regulations regarding third party access to infrastructure, The Storage of Carbon Dioxide (Access to Infrastructure) Regulations 2011 or The Storage of Carbon Dioxide (Access to Infrastructure) Regulations (Northern Ireland) 2015. The regulations are premised on fair, open and non-discriminatory access to networks. They set out that any "third party" seeking to join the network can apply to the owner of the transport or storage infrastructure in question who must consider the access request.

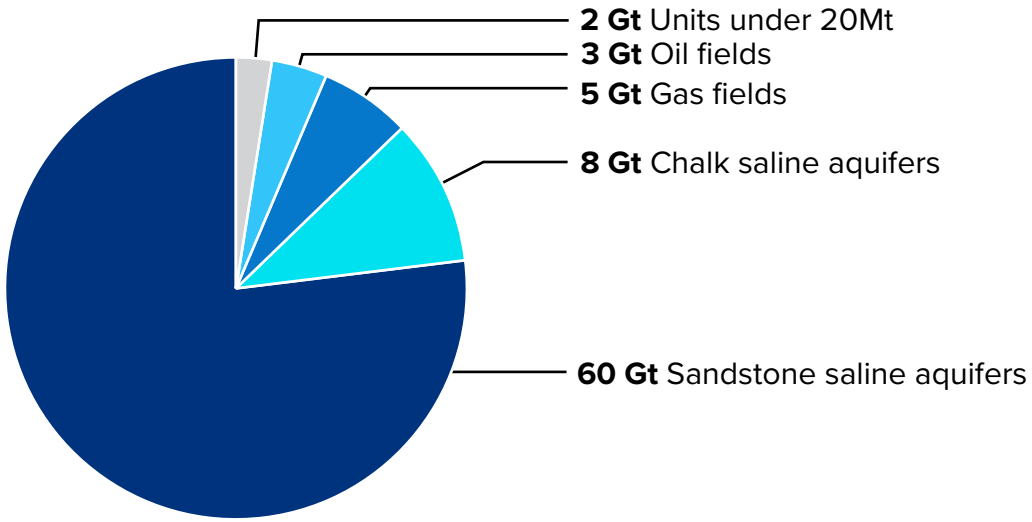
The government is planning to review the regulations in 2024 in consultation with the devolved authorities and may, pursuant to a power under the Energy Act 2023, amend, revoke or replace the existing legislation, to ensure it remains fit for purpose.

Delivering CO_2 Storage for the 2030s and beyond

Substantial CO_2 storage potential

With one of the largest potential subsurface storage capacities in Europe, the UK can lead the world in the provision of CO_2 transport and storage services. The UK's CO_2 storage database identifies over 500 potential sites for geological storage of CO_2, with an estimated 78 billion tonnes of theoretical CO_2 storage capacity on the UK Continental Shelf (UKCS) in either deep saline aquifers or depleted oil and gas fields.[38] The reservoirs where captured CO_2 would be injected for the selected Track-1 clusters of HyNet and the East Coast Cluster are depleted oil and gas fields, and saline aquifers, respectively.

Figure 7: Overall UK Storage Capacity in Offshore Geological Formations, Modified from UK Storage Appraisal Project.[39] The Majority of this Capacity Resides in Saline Aquifers.



Overall UK CO_2 storage capacity in offshore geological formations by type of store
Source: Based on Bentham et al. (2014) CO_2 storage Evaluation Database

[38] Michelle Bentham and others (2014), 'CO_2 Storage Evaluation Database CO_2 Stored). The UK's online storage atlas', Energy Procedia, Vol. 3, https://doi.org/10.1016/j.egypro.2014.11.540

[39] Energy Technologies Institute (2023), 'UK Storage Appraisal Project (UKSAP)', https://www.eti.co.uk/programmes/carbon-capture-storage/uk-storage-appraisal-project

Characteristics of CO_2 Stores	
Depleted oil and gas fields	**Saline aquifers**
Reservoir rock after hydrocarbon extraction has ceased	Reservoir rock that contains salty non-potable water
Mostly small stores	Usually significantly larger
More historical geological data	Requirement for new data and appraisal
Potential to re-use infrastructure	Likely to require newbuild infrastructure
Legacy well integrity risk	Potentially lower well integrity risk

Although suitable stores can be found both onshore and offshore, the current focus for UK CO_2 storage opportunities are offshore options due to the scale of deployment needed to meet our ambitions. By harnessing the potential of the UKCS' significant subsurface storage capacity, captured CO_2 can be injected into the subsurface usually at depths greater than 800 metres below the seabed, where it is permanently sequestered.

Deep geological storage of CO_2 is the secure containment of CO_2 in CCS systems. While the risks will vary on a site-specific basis, a report commissioned by Government indicates a very high level of confidence in the long-term security of CO_2.[40] The UKCS is a well-regulated environment and a CO_2 storage site will only be granted a CO_2 storage permit if the North Sea Transition Authority (NSTA) is satisfied that, under the proposed conditions of use of the storage site, there is no significant risk of leakage or harm to the environment or human health. This further reinforces the degree of confidence that may be placed in CO_2 containment for storage sites that have received a permit.[41]

The UK national CO_2 storage database provides an overview of CO_2 storage opportunities around the UK and enables industry and researchers to access non-confidential information to inform their plans for UK-wide industrial decarbonisation by CCUS.[42] Through the Industrial Decarbonisation Research and Innovation Centre (IDRIC) CO_2 Stored 2.0 project, funded by UK Research and Innovation, ongoing work will deliver up-to-date information on the UK subsurface storage resource for all UK clusters to plan emissions reductions by CCUS.[43] The Energy Act 2023 provides the NSTA with powers to require carbon storage licensees to retain and report information and samples gathered as part of activities associated with the geological storage of CO_2 and enables the NSTA to publicly disclose this information after a suitable confidentiality period. These powers will ensure valuable information collected by storage licensees is appropriately preserved and, in due course, made available for the benefit of the sector more broadly, expanding the information already made available through the NSTA's National Data Repository.[44]

[40] Department for Business, Energy & Industrial Strategy (2023), 'Deep geological storage of carbon dioxide (CO_2), offshore UK: containment certainty' carbon dioxide (CO_2), offshore UK: containment certainty', https://www.gov.uk/government/publications/deep-geological-storage-of-carbon-dioxide-co2-offshore-uk-containment-certainty

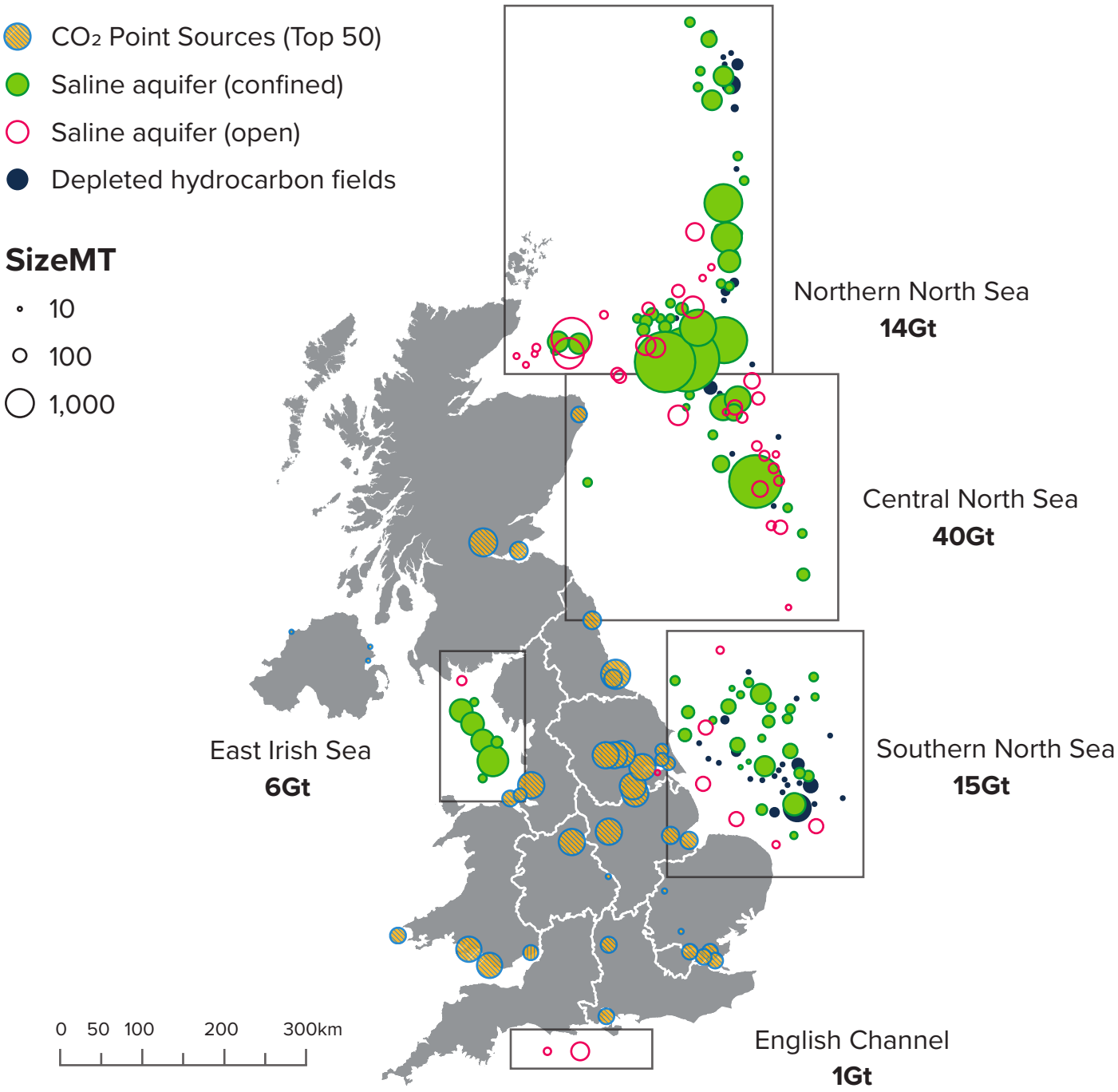
[41] Michelle Bentham and others (2014), 'CO_2 STORage Evaluation Database CO_2 Stored). The UK's online storage atlas', Energy Procedia, Vol. 3, https://doi.org/10.1016/j.egypro.2014.11.540

[42] CO_2 Stored (2023), 'Project FAQs', https://www.co2stored.co.uk/home/about_faq

[43] Industrial Decarbonisation Research and Innovation Centre (2022), 'Carbon Dioxide Stored 2.0 - Next generation of the UK's carbon dioxide storage database', https://idric.org/project/mip-6-4/

[44] UK National Data Repository (2023), 'Welcome to the UK National Data Repository (NDR)', https://ndr.nstauthority.co.uk/

Figure 8: Distribution of Storage Capacity in the UK Continental Shelf



Storage units with less than 20 Mt of storage capacity are not included in this figure

Delivering sufficient storage capacity to meet the needs of carbon capture projects

Measuring storage performance

From a storage capacity perspective, tracking our progress in meeting carbon budgets requires us to consider two sets of metrics:

- Storage capacity volume (megatonnes) is key to understanding the potential operational lifetime of a store, the potential to scale-up injectivity and the overall number of stores to be developed.
- Injection rate (megatonnes per annum – Mtpa) is key to understanding storage performance and meeting short-term milestones.

Both metrics are needed to understand the required build-out rates and operation of stores as many will require significant operation periods to utilise their full capacities and reach their optimal injection rates.

As the CCUS sector develops it is important that CO_2 transport and storage companies grant visibility and transparency on these metrics to existing and future users of CO_2 networks. To enable this, visibility and transparency will be underpinned both in the economic licence for CO_2 transport and storage and the CCS Network Code. The use of methodologies such as the CO_2 Storage Resources Management System (SRMS), developed by the Society of Petroleum Engineers (SPE), can support this visibility and transparency.[45]

Storage build-out rate

Offshore exploration and appraisal activity typically takes several years to complete due to the uncertainty associated with evaluating a subsurface CO_2 store. Collecting and analysing the datasets required to be confident of an investment decision, alongside development activity and regulatory applications, means time between project initiation and first CO_2 injection can take up to ~10 years. The considerable uncertainty around the activity required during both appraisal and development make it challenging to predict which stores will be successful and when individual candidate stores may be able to begin storage of CO_2.[46] Stores needed to meet 2035 volumes will require significant appraisal activity to take place in the second half of this decade to give sufficient time for development activity.

Operational stores may require time to 'ramp up',[47] not reaching their maximum injection rate until a few years after injection commences. This ramp up phase allows time for confidence to be gained in the integrity and likely performance of the store. During this period, clear and transparent engagement between the operators of CO_2 transport and storage networks and the users of their networks will be important. The economic regulatory framework established by government and enabled through the economic licence for CO_2 transport and storage and CCS Network Code seeks to facilitate this engagement by establishing appropriate periods for forecasting of storage capacity and network availability.

[45] Society of Petroleum Engineers (2017), 'CO_2 Storage Resources Management System', https://www.spe.org/industry/docs/SRMS.pdf
[46] Uncertainty associated with subsurface stores should significantly reduce as a project matures.
[47] The time to ramp up may be due to technical reasons, which could include engineering requirements such as pressure management considerations, and/or non-technical reasons which could be related to cost, CO_2 supply and location.

The potential build-out rate of stores needs to be accounted for when considering how the UK's geological storage potential is translated into operational stores, as many stores may be needed between 2033 and 2037 to ensure the UK stays on track to meet net zero in 2050, and to maximise potential economic opportunities. Recent work by the NSTA estimates that we may need to appraise up to 60 candidate stores before 2035 to be confident of providing sufficient injection capacity based on demand forecasts. In the longer term, the NSTA estimates that more than 100 operational stores could be required to support achievement of net zero.[48]

Securing sufficient subsurface storage capacity

To be ready for commercial CCS operations, significant time and financial investment is needed to confirm the existence of suitable CO_2 storage sites. Whilst the UKCS subsurface is well calibrated by substantial data collected via the oil and gas industry, the prediction of subsurface outcomes is inherently uncertain. At present, the full realisation of the potential for storing CO_2 is unknown; however, it is quite likely that some prospective stores will be proven to be unsuitable after exploration and appraisal activity is performed. Appraisal activity increases confidence that a candidate store can permanently and safely store CO_2 and reduces uncertainty on injection rates.

There are currently 27 carbon storage licences on the UKCS that will undertake exploration and appraisal activity, 21 of which were offered for award in May 2023 as part of the UK's first carbon storage licensing round. The first carbon storage licensing round is a significant step forward in the development of CCS in the UK. These new licences could, if all were to be successfully developed, store up to 30 Mt CO_2 per year by 2030, almost 10% of the UK's annual greenhouse gas emissions (which were 341.5 Mt in 2021).[49] Future licensing rounds will be required to ensure that sufficient candidate subsurface storage sites have been licensed and appraised in time to help the UK meet its net zero targets.

In 2024 we will develop policies to secure sufficient storage capacity and reduce storage risks. These include:

- Exploring policy options to incentivise accelerated appraisal activity.
- Supporting the NSTA and other stakeholders on licensing and appraisal strategy to ensure sufficient CO_2 injectivity is available to meet projected demand.
- Using high reasonable scenarios for CCUS demand to mitigate against the development of shortfalls in storage volume or capacity.

[48] North Sea Transition Authority (2023), 'Huge net zero boost as 20 carbon storage licences offered for award', www.nstaauthority.co.uk/new-publications/huge-net-zero-boost

[49] North Sea Transition Authority (2023), 'Net zero boost as carbon storage licenses accepted', https://www.nstauthority.co.uk/news-publications/net-zero-boost-as-carbon-storage-licences-accepted/

Ensuring resilience

Our vision is for CO_2 storage infrastructure that is reliable, resilient, and economically efficient; a landscape in which emitters and society have confidence in the CO_2 storage service provided by transport and storage providers. Storage infrastructure will need to be reliable so that emitters seeking to sequester their CO_2 can have confidence that networks and stores will be able to accept their CO_2 at the time that they need to flow.

Our CO_2 storage infrastructure will be resilient, minimising the risk of business interruption for emitters. Where one store is unable to meet its rates of injection to deliver the service required by emitters utilising that store, resilient storage infrastructure will mean that the emitter will see no interruption to its commercial operations and the CO_2 emissions will be abated. Resilient storage infrastructure could mean developing a range of operational stores in proximity to each other, developing flexible transportation options between stores and considering common CO_2 specifications to promote flexible and competitive markets. Achieving this vision will require cooperation between the bodies involved in the leasing, licensing and permitting of CO_2 stores. It will also require an understanding of how best to allocate potential storage capacity and how to develop an offshore transportation network accordingly, considering other potential users of these storage assets and other users of the marine space. This necessity is part of the reason why government has established the framework for the economic regulation of CO_2 transport and storage networks.

Commercialisation of UK CO_2 storage capacity

The companies providing sequestration services will be best placed to manage the risks that come with reliable and resilient delivery. The government's role in enabling the development of this new opportunity is to:

- Provide clarity to developers on how a licensee may see a return on investment. This applies to cluster sequencing and beyond.
- Ensure developers have line of sight to CO_2 supply, including undertaking activity to enable imports of CO_2, and the development of non-pipeline transport.

We envisage that government's role in these areas will reduce over time as this new efficient and essential decarbonisation service develops, providing those best able to leverage their CO_2 storage expertise and capabilities with new markets (first in the North Sea and then potentially globally). This will mean that the market in the 2030s should look very different from today. We may see the provision of different types of services across the offshore CO_2 transport and storage value chain.

We may see the emergence of new entities who seek to own, operate and maintain pipelines offshore: connecting CO_2 exit points on the mainland to stores in the North Sea, akin to Offshore Electricity Transmission owners who own and maintain electricity transmission assets connecting offshore windfarms with the electricity grid onshore, or the current hydrocarbon pipeline networks flowing CO_2 to subsurface stores rather than extracting hydrocarbons.

In addition, we may see independent storage companies offering CO_2 storage services to larger network and store operators or seeking third party access to offshore CO_2 pipelines developed by others. We may also see stores being appraised and granted a carbon storage permit, and then released to the market and acquired by other CO_2 storage operators.

The economic regulation framework established under the Energy Act 2023 recognises that, at least initially, CO_2 transport and storage infrastructure will be operated as natural regional monopolies. However, there is flexibility within the economic regulation framework to allow it to evolve as the sector matures. Given the long lead in times required for leasing, licensing and permitting of stores, to unlock the potential for our offshore subsurface storage sites for CCS, in 2024 we intend to:

- Work with the NSTA, Crown Estate Scotland (CES), The Crown Estate (TCE), and industry groups like the North Sea Transition Forum's Sub-Surface Taskforce[50] and other stakeholders to explore the optimal approach to carbon storage licensing and leasing, including the potential for future leasing and licensing rounds for offshore areas.
- Work to explore ways to increasingly streamline the regulatory processes, interfaces and the pathway to storage permitting and transport and storage economic licensing.
- Engage stakeholders to develop options to deliver a more competitive market for CO_2 storage services with a decreasing dependency on government financial support and moving towards a self-sustaining market for CO_2 storage, whilst maintaining effective economic regulation where monopolies endure.
- Collaborate with partners such as the NSTA, TCE, CES, and with Devolved Administrations to enable the management and delivery of multiple government targets and ambitions on net zero, energy security, the Fisheries Act, the environment and levelling up – all in response to the growing demands on the finite resources of the seabed. This is also why the government has established the Marine Spatial Prioritisation programme in England to consider all future demands on the marine space and to support the holistic and strategic planning needed to optimise future use of our seas.

Maximising the opportunities from the UK's storage capacity

A market for CO_2 storage services

The development of the UK's vast offshore CO_2 subsurface storage potential not only helps to decarbonise key industrial sectors within the UK but allows us to offer CO_2 storage services to other countries, unlocking a new market for CO_2 imports and providing additional job opportunities, whilst helping wider international decarbonisation efforts.

Cross-border CO_2 transport and storage (T&S) networks would generate strategic national assets. Commercialisation of UK stores for CO_2 imports could support the development of the domestic CCS market and expedite the transition away from taxpayer support. This opportunity is particularly important for domestic regions with a high prevalence of CO_2 storage but a low prevalence of CO_2 emitters.

The growth of a CO_2 import market could increase the resilience of the UK's domestic CO_2 storage market through diversification of storage providers and could expedite

[50] Subsurface Task Force (2023), 'Purpose', https://subsurfacetaskforce.org.uk/

the deployment of infrastructure needed to establish NPT networks (e.g. ships), vital for importing CO_2. Furthermore, supporting the development of interoperable cross-border T&S networks, including potential cross border pipelines, could allow the UK to further increase store resilience by providing the option to temporarily export CO_2 for storage in third countries in the event of problems with a store's performance or with flows of CO_2 from domestic emitters.

The Carbon Capture and Storage Association (CCSA) has analysed how a Europe-wide market for CO_2 storage and the creation of a new CO_2 export service by the UK can lower cost for UK users in the development of a CCUS industry. It highlights how a balance of UK and non-UK CO_2 within the initial CO_2 T&S networks can reduce the cost-per-unit of CO_2 for UK users of the network, thereby reducing the cost to consumers and UK taxpayers through the revenue support arrangements within the CCUS business models.[51]

The CCSA's 2035 Delivery Plan indicates that around 20 Mt per year of carbon dioxide could be safely imported to the UK and stored in subsea geological reservoirs from neighbouring countries by 2035.[52] This presents a significant opportunity, but also a challenge, as imported CO_2 will require additional storage capacity above that which is required to meet the UK's own net zero targets. Additional storage sites will need to be appraised over the next decade to maximise the chance of meeting this trajectory.

According to EU Commission estimates, the European Union could need to capture up to 550 million tonnes of CO_2 annually by 2050 to meet its net zero objective.[53] The development of interconnected CO_2 transport and storage networks are likely to be an important factor in achieving this level of abatement. Stimulated by the growth of interoperable CCUS ports and a fleet of CO_2 ships, or cross border pipelines, these networks could develop in the North Sea Region by the 2030s, with UK storage sites playing a central role in supporting regional decarbonisation.

The UK is well placed – both geographically and geologically – to help EU Member States meet future abatement targets by offering European emitters optionality and resilience in storage site selection. The UK's potential role is recognised by the CCUS Forum, a group of leading representatives from the EU institutions, EU and third countries governments.[54]

Enabling future cross-border CO_2 networks

To realise the opportunity from a market for CO_2 storage services, in 2024 the government will work with stakeholders to explore what actions may be required to enable a new commercial framework to support international imports. For the initial clusters, this would include consideration of how the T&S business model[55] would account for imports and how the transport and storage of these volumes would be addressed in the CCUS Network Code.[56]

[51] Carbon Capture and Storage Association (2023), 'CCSA Position Paper: Europe-wide market for CO_2 storage', https://www.ccsassociation.org/resources/

[52] Carbon Capture and Storage Association (2022), 'CCUS 2035 Delivery Plan' https://www.ccsassociation.org/resources/download?id=2081

[53] European Commission (2023), 'Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act)', https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0161

[54] European Commission CCUS Forum (2022), 'Towards a European Cross-Border CO_2 Transport and Storage Infrastructure', https://circabc.europa.eu/ui/group/75b4ad48-262d-455d-997a-7d5b1f4cf69c/library/435ae9cd-1cb6-49a9-9311-f77c21c64d82/details

[55] Department for Business, Energy & Industrial Strategy (2020), https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-business-models

[56] Department for Business, Energy & Industrial Strategy (2022), 'CCS Network Codes - Indicative Heads of Terms', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1085943/ccs_network_code_draft_HoT__200622_.pdf

A further consideration is how cross-border CO_2 transport and storage networks will be regulated and permitted. Sir Patrick Vallance's Pro Innovation (Green Industries) Review acknowledges this, recommending that: 'The government should work with international partners to remove regulatory barriers to the cross-border movement of CO_2 to help ensure that the UK can maximise the economic potential of providing CO_2 transport and storage services.'[57]

We have already made good progress in addressing some regulatory barriers. In September 2022, for example, the UK deposited a formal declaration of provisional application of the 2009 amendment to the London Protocol,[58] allowing the UK to enter into bilateral agreements/arrangements with third party countries for the cross-border transport of CO_2 for permanent subsea storage. We will explore the possibility of signing bilateral agreements/arrangements with countries interested in exporting CO_2 to the UK for permanent storage.

The UK government is playing an active role in Europe to support the development of regional CO_2 T&S networks (see Chapter 1). The UK will continue to engage in dialogue with the EU with regards to how our respective frameworks, in areas such as CO_2 storage licensing or emissions trading scheme regulation, can support the development of potential cross-border CO_2 T&S networks in the future.

This chapter has outlined the key developments required to facilitate a transition out of the market creation phase and to promote a significant ramp up in the deployment of CCUS in the UK. From amendments to the process for granting economic licences; the move towards a competitive allocation process for capture contracts; the evolution of T&S business models to reflect an increased role for the private sector in managing cross-chain risks; consideration on the strategic direction of CO_2 transport networks; the development of non-pipeline transport networks; the streamlining of leasing, licensing and permitting processes to accelerate subsurface storage appraisal and the enablement of CO_2 imports.

Taken together, these developments will kick start Phase Two: the market transition phase. By the mid 2030s, the amount of CO_2 annually stored may need to increase to at least 50 Mtpa.[59] The following chapter – Chapter 5 – outlines the range of sectors whose decarbonisation could be supported by CCUS technology.

[57] HM Treasury (2023), 'Pro-innovation Regulation of Technologies Review: Green Industries', https://www.gov.uk/government/publications/pro-innovation-regulation-of-technologies-review-green-industries

[58] International Maritime Organization (2019), 'Carbon Capture and Sequestration', https://www.imo.org/en/OurWork/Environment/Pages/CCS-Default.aspx

[59] Department for Energy Security and Net Zero (2023), 'Powering Up Britain: Net Zero Growth Plan (2023), https://www.gov.uk/government/publications/powering-up-britain

Chapter 5:

Capture Sectors

CCUS is a versatile technology that has a role to play in decarbonising multiple sectors. It will help decarbonise our electricity system, our heavy industries such as cement and chemicals, our waste and aviation sectors, and support the growth of the hydrogen economy. It will also be needed to support delivery of negative emissions by offsetting remaining sectoral emissions. The role of CCUS and the barriers to deployment vary in each sector.

Powering the UK

Power CCUS is ready to provide dispatchable low carbon generation. Renewables will play a key role in our future electricity system but to decarbonise whilst maintaining security of supply and keeping system costs low, we will need to balance renewable variability against demand. This is where power CCUS comes in.

As noted by the Committee on Climate Change (CCC) in their report on delivering a reliable decarbonised power system, "the government must give equal focus to low-carbon flexible solutions as to the full delivery of its existing renewables and nuclear commitments".[60] Analysis that was first published alongside the Net Zero Strategy in 2021 suggests that up to 10GW of power CCUS could be needed by 2035.[61]

Power CCUS forms a critical part of the CCUS programme and the need for it is driven by the demands of our energy system, the need to decarbonise our power sector by 2035 and to deliver the power sector's contribution to the delivery of Carbon Budget 6. Therefore, the future of power CCUS will be strongly guided by the development of wider energy policy initiatives such as the Review of the Electricity Market Arrangements (REMA). The next REMA consultation is due out shortly and will contain proposals on how low-carbon flexibility, including power CCUS, can be bought forwards. We will consider how policy proposals contained within the REMA consultation work alongside the competitive allocation processes that have been set out earlier in this document for the CCUS programme.

In the Net Zero Strategy, we also committed to deploying at least one power CCUS plant by the mid-2020s and we are currently in negotiations with Net Zero Teesside as part of Track-1 of the Cluster Sequencing Process. We are now looking to bring forward multiple additional CCUS projects by 2030 to put us on track to decarbonise the power sector by 2035, subject to security of supply. Deployment of additional projects will be subject to value for money, affordability and availability of storage. In addition, we will need to continue to ensure that power CCUS can play a dispatchable role in the electricity system whilst being incorporated into the CO_2 transport and storage system alongside other users as efficiently as possible.

[60] The Climate Change Committee (2023), 'Delivering a reliable decarbonised power system', https://www.theccc.org.uk/publication/delivering-a-reliable-decarbonised-power-system/

[61] Department for Business, Energy & Industrial Strategy (2021), 'Energy and emissions projections: Net Zero Strategy baseline (partial interim update December 2021)', https://www.gov.uk/government/publications/energy-and-emissions-projections-net-zero-strategy-baseline-partial-interim-update-december-2021

The Dispatchable Power Agreement (DPA)[62] is the business model we have developed for power CCUS and, as part of our recent call for evidence response, we committed to the continued use of the DPA in the 2020s for Track-1 expansion and Track-2.[63]

Ensuring our industrial sector competes in the global market

CCUS is of critical importance to decarbonising industry (e.g. cement, chemicals and refining); in many cases, there is no technological alternative to CCUS capable of achieving the emissions reductions required for a Carbon Budget 6 (CB6) consistent pathway. This is because, according to the CCC, around 10.2 Mt CO_2 of industrial emissions are process emissions (they result from chemical or physical reactions in industrial processes) and therefore cannot be avoided by switching to alternative fuels.[64] For example, process emissions are a particular feature of cement production, accounting for 60 to 70% of emissions.

Providing support to decarbonise through CCUS will help industry remain competitive in the net zero economy and help preserve and build on the 2.4 million direct jobs[65] and £200 billion Gross Value Added[66] that the sector provides the UK.

The Net Zero Strategy set an ambition to deliver 6 Mt of CO_2 of industrial CCUS by 2030, and 9 MtCO_2e by 2035. In practice, our modelling assumptions indicate that a 'least societal cost' pathway to CB6 will require capturing and storing around 10 megatonnes per annum (Mtpa) of CO_2 by 2035. Most emissions to be captured are in industrial clusters – about 6 Mt for CB6 – but there remains over 4 Mt in dispersed sites, many of which will need rapid advancement of non-pipeline transport (NPT).

The key design aspects of the business models for industrial carbon capture were outlined in an update in December 2022 and the latest iteration of the contract terms was published in October 2023.[67] In March 2023, we announced a Track-1 project negotiation list, comprising three industrial projects, which are now in negotiations for business model support.

Carbon capture and usage (CCU), in which captured CO_2 is used rather than stored in geological formations, may also play a role for some industrial facilities in decarbonising, where the application of CCU results in the permanent abatement of CO_2.

CCU technologies could offer a complementary, yet smaller in scale, solution for net zero to CCS. CCU could also represent an alternative solution for dispersed sites that have limited transport and storage options and have a role in aiding the development of a low carbon products market.

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[62] Department for Business, Energy & Industrial Strategy (2022), 'Carbon capture, usage and storage (CCUS): Dispatchable Power Agreement business model', https://www.gov.uk/government/consultations/carbon-capture-usage-and-storage-ccus-dispatchable-power-agreement-business-model

[63] Department for Business, Energy & Industrial Strategy (2022), 'Future policy framework for power with carbon capture, usage and storage (CCUS): call for evidence', https://www.gov.uk/government/calls-for-evidence/future-policy-framework-for-power-with-carbon-capture-usage-and-storage-ccus-call-for-evidence

[64] International Energy Agency (2020), 'CCUS in Clean Energy Transitions', https://www.iea.org/reports/ccus-in-clean-energy-transitions

[65] Office for National Statistics (2023), 'Employee jobs by industry (JOBS03)', https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employeejobsbyindustryjobs03

[66] Office for National Statistics (2023), 'GDP output approach - low level aggregates', https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates/current 'Low-level aggregates of UK output gross value added (GVA), ONS (2023)

[67] Department for Business, Energy & Industrial Strategy (2020), 'Carbon capture, usage and storage (CCUS): business models', https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-business-models

CCU projects have been supported through innovation funding such as the CCU Demonstration innovation programme (as part of the Energy Innovation Programme 2017 – 2021) and the CCUS Innovation 2.0 programme (part of the Net Zero Innovation Portfolio 2021 – 2025). CCU is currently ineligible for business model support under the CCUS programme. In the Industrial Carbon Capture (ICC) business model update published in October 2021, we set out that further work is needed to determine whether the ICC business model is the most suitable form of support for CCU, including evidence relating to the permanency of CO_2 stored. We will conduct further work in 2024, including committing to engage with industry, to consider the potential role of CCU within the CCUS framework.

Cleaning up our waste

All efforts must be made to prevent waste from arising in the first instance. Where waste does occur, we need to manage it in the most resource-efficient way possible: preparing items for re-use, before recycling and finally recovering energy from those wastes that cannot be prevented. The government recognises that even with policies for greater waste prevention, reuse and increased recycling, there will still be a need to manage residual waste.

CCUS is the only net zero compliant technology for residual waste management facilities. The energy from waste (EfW) fleet is currently the dominant technology for managing municipal residual waste, but there are other emerging technologies that can produce useful products and may make up a share of the residual waste management sector in the future.

The biogenic content of mixed municipal waste means that by deploying CCUS at these facilities, there will be an opportunity to offset emissions elsewhere in the economy and from hard-to-abate sectors through the delivery of negative emissions.

The latest update on the business model for waste carbon capture projects was published in October 2023.[68] In March 2023, we announced a Track-1 project negotiation list, including two EfW projects that are now in negotiations for business model support.

Creating new fuels for the future

Low carbon hydrogen is expected to play a key part in our future energy system, supporting UK energy security and playing a critical role in helping vital British industries transition away from expensive fossil fuels. It can provide greener energy for industry, power, transport, and potentially heat in buildings, while long duration energy storage, primarily from hydrogen, could provide £13 billion to £24 billion in savings to the power system between 2030 and 2050.[69]

The British Energy Security Strategy saw the UK's ambition double to up to 10GW of low carbon hydrogen production capacity by 2030, subject to affordability and value for money, and set out our intention for up to 1GW of electrolytic and up to 1GW of CCUS-enabled hydrogen production operational or in construction by 2025.[70] The UK Hydrogen Strategy and subsequent Hydrogen Strategy Updates to the Market[71] set out the government's aim of supporting multiple production technologies to meet our stretching ambitions, including

[68] Department for Business, Energy & Industrial Strategy (2020) 'CCUS capture, usage and storage: business models', https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-business-models

[69] AFRY (2022), 'The Benefits of Long Duration Electricity Storage', https://afry.com/en/newsroom/news/benefits-long-duration-electricity-storage

[70] Department for Business, Energy and Industrial Strategy (2022), 'British energy industrial strategy', https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[71] Department for Business, Energy and Industrial Strategy (2021) UK hydrogen strategy https://www.gov.uk/government/publications/uk-hydrogen-strategy

both electrolytic 'green' and CCUS-enabled 'blue' hydrogen production.[72] Analysis by both the department and the Climate Change Committee has previously indicated that CCUS-enabled hydrogen will be important in scaling up production into the 2030s and can be consistent with our net zero commitments.[73] Other production routes, including nuclear-enabled hydrogen and biomass and waste-related technologies, could also play a role in our hydrogen economy, while hydrogen Bioenergy with CCS (BECCS) could deliver vital negative emissions to help meet net zero.

CCUS-enabled hydrogen projects have previously been invited to bid through the Phase-2 Cluster Sequencing process. In March 2023 we published the Track-1 Project Negotiation List, which included two hydrogen projects: Essar Energy Transition's Hydrogen Production Plant in the HyNet cluster and BP's H2Teesside in the East Coast Cluster. These steps are crucial to building early momentum, giving industry the confidence they need to invest in and commit to hydrogen and ultimately take us to a thriving hydrogen economy fit for meeting the demands of net zero as set out in the UK Hydrogen Strategy. We have also committed to designing new business models for hydrogen transport and storage infrastructure by 2025, which will be essential to grow the hydrogen economy and provide security for producers and consumers of hydrogen.

Other low carbon fuels also have the potential to be combined with CCUS to maximise carbon savings, including sustainable aviation fuel discussed below.

Creating clean fuels for flying

Sustainable aviation fuel (SAF) can be easily blended with conventional jet fuel. It can achieve lifecycle emission savings of over 70% when fully replacing fossil-derived kerosene and can be used in existing aircraft, engines, and infrastructure without modification. The government's Jet Zero Strategy recognised SAF as a vital tool for reducing emissions in the difficult to decarbonise aviation sector.[74]

SAF can be made from a variety of feedstocks including municipal solid waste, recycled carbon fuels (using unrecyclable plastic and waste industrial gases) and, in time, from harnessing low carbon electricity to produce a synthetic fuel. The government has committed that it will only provide incentives for SAF made from wastes, residues, or low carbon energy ('power to liquid' fuels).

Across most of the main SAF production pathways, CCUS can be incorporated to capture carbon streams released during the production process and reduce the carbon intensity of the resulting SAF. The inclusion of CCUS in SAF production would allow emission savings to be maximised while making the best use of feedstocks. In some cases where biogenic feedstock is used, SAF production with CCUS has the potential to result in net negative emissions across its lifecycle and could contribute to 2030 ambitions for engineered greenhouse gas removals. In the case of power to liquid, CO_2 is used as an input in the production process and can therefore utilise CO_2 from other sectors where CCUS has been deployed.

[72] Electrolytic hydrogen refers to the production of hydrogen through electrolysis, where electricity is used to split water into hydrogen and oxygen. The hydrogen produced from this process is described as 'green' when the electricity comes from renewable sources. CCS-enabled hydrogen production uses steam methane reformation, where natural gas is reacted with steam to form hydrogen.

[73] The Climate Change Committee (2020), 'The Sixth Carbon Budget', https://www.theccc.org.uk/publication/sixth-carbon-budget/

[74] Department for Transport (2022), 'Jet Zero Strategy: delivering net zero aviation by 2050', https://www.gov.uk/government/publications/jet-zero-strategy-delivering-net-zero-aviation-by-2050

The government is introducing a mandate on fuel suppliers to supply SAF from 2025 and has committed to 10% SAF by 2030. The scheme will incentivise emission reductions by providing support in proportion to emission savings. The inclusion of CCUS in SAF production would allow emission savings to be maximised while making the best use of feedstocks.

The UK is supporting the development of next generation SAF production pathways that have the potential to achieve greater carbon savings and will use a greater range of feedstocks. The right market conditions are needed to attract private investment to scale these first-of-a-kind production plants. Access to CCUS will be critical to the success of some SAF production pathways, including providing opportunities for green jobs and growth and reducing our reliance on imports.

The government is already supporting three SAF projects through the Advanced Fuels Fund that are set to be completed in the late 2020s and have the potential to incorporate CCUS and produce negative emissions, subject to appropriate monitoring, reporting and verification criteria for durable removals.[75]

The production of low carbon fuels for other transport modes, like road and maritime, may also be able to utilise CCUS. We will conduct further work to establish the role of CCUS in these applications and how similar incentives for the use of CCS can be attributed to these fuels in both existing schemes like the Renewable Transport Fuel Obligation and any future schemes for modes beyond road and aviation.

Removing greenhouse gases from the atmosphere

Greenhouse Gas Removal (GGR) technologies will be essential for reaching net zero. Even with all our efforts to decarbonise, some residual emissions from hard to decarbonise sectors will remain, for which negative emissions will be needed[76] (as highlighted by the 2023 Intergovernmental Panel on Climate Change report).[77] As we set out in the Net Zero Strategy and confirmed in the Carbon Budget Delivery Plan, we have an ambition to deploy at least 5 megatonnes per annum (Mtpa) of engineered CO_2 removals by 2030 rising to up to 23 Mtpa by 2035 and potentially scaling to 75 to 81 Mtpa by 2050.[78]

Engineered GGRs cover a wide range of technologies, some of which require access to a CO_2 transport network to permanently store the removed CO_2. This includes technologies such as Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS). We aim to support a mix of GGR technologies, noting the most significant removals at scale in the 2030s are likely to come from those technologies which require geological storage of CO_2. Our modelling assumptions suggest power BECCS is expected to be one of the largest GGR contributors to our net zero ambitions, and we expect a range of GGR technologies to come forward, with the sector both becoming a major user of the CO_2 transport network by the mid-2030s and growing in non-CCUS technologies.

[75] See "A review of Greenhouse Gas Removal (GGRs) standards and methodologies' (published alongside the CCUS Vision).

[76] For a technology to deliver a negative emission, it must remove more greenhouse gases from the atmosphere than are generated from the carbon removal process, making the process is net negative. Our criteria for robust negative emissions is threefold:
Net negativity: more carbon is removed from the atmosphere than is generated in a GGR process;
CO_2 source: CO_2 must be captured directly from the atmosphere or seawater;
Permanence: the removed carbon is contained in a highly-durable store.

[77] Intergovernmental Panel on Climate Change (2023), https://www.ipcc.ch/report/sixth-assessment-report-cycle/ (B.5.1)

[78] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy', https://www.gov.uk/government/publications/net-zero-strategy, p.184, and Department for Energy Security and Net Zero (2023), 'Carbon Budget Delivery Plan', Annex B, Table 5, Quantified Policies Table - Policy 191, https://www.gov.uk/government/publications/carbon-budget-delivery-plan/carbon-budget-delivery-plan

We are also publishing an update which sets out further detail on key elements of both the GGR and power BECCS business models' design, including further detail on our monitoring, reporting and verification and life cycle assessment approach. It also provides an update on the eligibility criteria for GGR projects' application to Track-1 expansion for HyNet. The government will enable GGRs to apply to Track-1 expansion of the CCUS Programme under the criteria published today, and to Track-2 subject to criteria under development.

On BECCS, to date, we have published the government response to the power BECCS business model consultation (March 2023) and a response to the consultation on a GGR business model (June 2023). Following a power BECCS project submission process, we invited projects who passed the assessment to engage in formal discussions with the department. These discussions are an opportunity for government and the projects to discuss the assessment feedback and to explore pathways to future power BECCS deployment.

This chapter has outlined the capture sectors whose decarbonisation will be directly aided by CCUS technology. The decarbonisation and deployment of these sectors could play an essential role in helping the UK to meet its net zero targets.

Direct Air Carbon Capture and Storage

Greenhouse Gas Removals (GGRs) fall broadly into two categories; nature-based solutions such as afforestation and soil carbon sequestration, and engineering-based approaches such as Direct Air Carbon Capture and Storage (DACCS) and Bioenergy and Carbon Capture and Storage (BECCS). Some engineered GGRs require access to a CO_2 transport and storage network to permanently store the removed CO_2 – DACCS is an example of one of these technologies.

DACCS refers to a suite of GGR technologies that capture CO_2 directly from the atmosphere and sequester that CO_2 in permanent storage. There are different types of DACCS technologies depending on the method used to separate the CO_2 from the atmosphere. While there are operational DACCS facilities globally, commercial deployment has not yet been achieved at scale. As well as connection to the CCS network, DACCS also needs a low-carbon energy supply.

We are investing £100 million in research and innovation for GGRs, including the Direct Air Capture and Greenhouse Gas Removal Innovation Competition. Phase 2 of the competition was announced in July 2022, with over £54 million of government funding awarded across 14 of the most promising demonstration projects, including three DACCS projects.

As highlighted by the National Infrastructure Commission, the GGR sector presents major economic opportunities for the UK. We intend to capitalise on the potential benefits of this emerging sector to deliver new export opportunities and support tens of thousands of high-quality green jobs across the country.

Annex: Current Economic Regulatory Regime for CO_2 Transport & Storage

Legislation, Licensing and the Role of Ofgem

Energy Act 2023

The Energy Act 2023 sets out a framework of economic regulation for transporting and storing carbon dioxide, as well as the duties, powers and functions given to Ofgem as the economic regulator. The economic regulation model gives the transport and storage industry the long-term revenue certainty that is needed to establish and scale up the first CO_2 transport networks. The regulatory model established is based on a range of precedents, including regulation of other utilities and, after consultation, was found to be the preferred business model. The Act also establishes mechanisms for financing carbon capture from industrial processes, low carbon hydrogen production, and from greenhouse gas removal technologies.

At least initially, carbon dioxide transport and storage infrastructure will be operated as regional monopolies, with a range of CO_2 transport network users and emitters who use different commercial models. Transport and storage economic licensing and independent regulatory oversight have been designed to protect network users, who initially will be either taxpayer or consumer funded, from anti-competitive behaviour such as monopolistic pricing. Even if network users are not taxpayer or consumer funded — either because over time network users do not need public funding or because an initial user's contract term has expired, and they are still connected to the network — users may still be exposed to the risk of monopolistic pricing and so the economic regulation enabled by the Act remains appropriate.

An economic licence will allow a transport and storage company the right to charge users, with regulatory oversight in a monopolistic environment to ensure that these charges are in line with costings and allow a reasonable return on capital investment. The licence will also impose obligations on the operator regarding how they conduct their activities to safeguard the interest of users.

The North Sea Transition Authority (NSTA) and ministers in the Devolved Administrations (the Department for the Economy in Northern Ireland) remain the relevant licensing authorities for CO_2 storage under the powers set out in Chapter 3, Part 1 of the Energy Act 2008 to ensure the secure geological storage of CO_2.

The Energy Act 2023 supports CCUS business models through:

- Financial assistance – Providing the Secretary of State with UK-wide powers to provide financial assistance to support the establishment of CCUS and low carbon hydrogen production.
- Counterparty – The contractual nature of the revenue support arrangements and emitter business models requires a counterparty to manage the contracts

and act as a conduit for funding. The Act provides the Secretary of State with powers to designate and direct a counterparty.

- Competitive Allocation – Initial hydrogen production and industrial carbon capture (ICC) projects are expected to be allocated support through a bilateral process. In the medium term, the business models are expected to move to a more competitive allocation process (e.g. an auction-based system), similar to the CfD, to reduce costs to government and the consumer. The Act provides the Secretary of State with powers to appoint an allocation body and set out the allocation process in regulations and allocation frameworks.
- Gas Shipper Levy – The hydrogen production business model will initially be exchequer funded and transition to levy funding as soon as possible, subject to consultation and legislation being in place. The Act provides the Secretary of State with powers to appoint a levy administrator and to make regulations that will establish the levy.
- Licensing framework – The economic regulation model in the Act includes statutory objectives and grants legal powers to Ofgem, establishing an economic licensing framework under which an Ofgem-regulated licence will be required to operate and charge for the use of CO_2 transport networks. The licence will set out the Allowed Revenue an operator can receive, where regulatory oversight by Ofgem will ensure costs are economic and efficient.
- The accumulation of a fund for decommissioning and provisions for asset re-use – The Act provides powers to ensure funds are in place for the safe decommissioning of carbon dioxide transport and storage infrastructure at the end of its operational lifetime. The Act also brings powers relating to the re-purposing of oil and gas assets for CCUS in line with current government policy.
- Special Administration Regime – The Act enables a Special Administration Regime, in the event of a CO_2 transport and storage company insolvency, to support the ongoing operation of the CO_2 transport network, to prioritise its rescue as a going concern, in the interests of users and to secure the ongoing safety and security of the network.
- Statutory transfer scheme – The Act gives rights to the Secretary of State to step in, in a licence termination scenario, to secure the ongoing operation of the transport and storage network or to make sure the infrastructure is correctly decommissioned. In this regard the Secretary of State may take on the role of transport and storage operator of last resort.
- Greenhouse gas removal – The Act will deliver on the commitments in the Net Zero Strategy to make sure engineered removal of greenhouse gas emissions count towards our carbon budgets.

CCUS Strategy and Policy Statement

The Energy Act 2023 also gives Secretary of State the power to designate a Strategy and Policy Statement that they and Ofgem must have due regard to when carrying out their CCUS related functions. This is consistent with the approach in other economically regulated sectors.

The statement would set out:

- the strategic priorities and other main considerations of government in formulating its carbon dioxide capture, usage, and storage policy for the UK,
- the particular outcomes to be achieved as a result of the implementation of that policy,

- the roles and responsibilities of persons (primarily the Secretary of State and the economic regulator) who are involved in implementing that policy or who have other functions that are affected by it.

The statement must be reviewed at least every 5 years but can be reviewed earlier in certain circumstances: if there is a general election; if Ofgem are no longer able to comply with the statement; if there is a significant policy change; or if Parliamentary approval was not met in the last review.

When the statement is first drafted and each time it is reviewed the Secretary of State must consult Scottish Ministers, Welsh Ministers and the Department for the Economy in Northern Ireland.

The statement must be laid in Parliament and approved by both Houses before it comes into force.

Future Transport and Storage Economic Licensing

Currently, through the cluster sequencing model, Secretary of State decides which network operators should be awarded a licence and the terms and conditions of the licence. This is because, initially, a significant amount of public financial support will be available to operators and this approach allows Secretary of State to conduct in-depth suitability and value for money assessments to safeguard the interest of taxpayers.

While the first transport and storage licences will encompass onshore transport, offshore transport and offshore storage under a single licence, the Act also enables CO_2 pipeline transport and CO_2 storage activities to be licensed as separate activities. Additionally, the Act provides for different "types" of licences to be created and granted for transport and storage activities, for example to facilitate separate "onshore" and "offshore" licences, for which substantially different licence conditions may become appropriate.

The Act allows for a procedure for licence applications to be established in secondary legislation. We anticipate this being in place for economic licences which are to be granted after the first licences are allocated through the government's cluster sequencing process. We also expect that at this point the responsibility for granting licences will pass from the Secretary of State to Ofgem. The exact timing of this will depend on the maturity of the CCUS market and the expected levels of continuing government financial support.

In the future, licence allocation could be done on a competitive basis which may provide better value for money for taxpayers and consumers. This is provided for in the Energy Act 2023, but an assessment will be needed to determine if this route would be appropriate and will depend on how the CCUS market develops and the breadth of market participants.

Revenue Support Agreement (RSA)

The purpose of the revenue model is to mitigate T&SCo exposure to revenue gaps during the early stages of development of the CCUS sector, when the market will not be sufficiently mature for T&SCo to mitigate this risk. Within the revenue model, Risk Mitigation Mechanisms (RMMs), which are primarily user funded, are designed to enable T&SCo to recover its allowed revenue from network users.

However, if RMMs are insufficient to address a revenue gap, then T&SCo will be entitled to Revenue Support as a last resort mechanism to enable T&SCo to recover any shortfall in Allowed Revenue allocated to T&SCo under the economic licence. For a T&SCo to receive Revenue Support, the T&SCo must enter into a Revenue Support Agreement (RSA) with the designated RSA counterparty. If Revenue Support is triggered, then the RSA counterparty will draw on funds from UK government (and potentially energy consumers) to allow the RSA Counterparty to make a direct payment to T&SCo. The RSA is viewed as a mechanism to support this industry on the road to a self-sustaining merchant market model for the expansion of the network and acquisition of new customers. As the market expands, it is anticipated that the importance of the RSA as a financial support mechanism will diminish and fall away. All stakeholders in the first four T&SCos agree that an evolution to a merchant model is evidence of success and it is the preferred model.

Government Support Package (GSP)

The GSP will offer protection to investors for specified high impact low probability risks that the private sector are not able to bear at an efficient price, or indeed any price. The risks covered will be CO_2 leakage at the store complex, other non-leakage geological events which cause T&SCo under its Storage Permit to suspend the injection of CO_2 at that Storage Site for a minimum period of three years and asset stranding due to insufficient demand for the T&S network. It consists of a number of bespoke contracts:

- The Supplementary Compensation Agreement which will provide certain payments to T&SCo if commercial insurance is unavailable or has been exhausted and a relevant liability arises.
- The Discontinuation Agreement provides the Secretary of State with the right to discontinue the GSP in certain specified circumstances and entitles investors to be compensated for their investment should the right to discontinue be exercised.

The Liaison Agreement provides a framework for effective governance and information flow between T&SCo and government.

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