Addressing regulatory challenges for offshore Geological Carbon Storage in the UK

Policy Brief

The Agile Initiative
September 2024

Suggested citation: Sutton, M., Muslemani, H., Smith, S. M., and Allen, M. (2024). "Addressing regulatory challenges for offshore geological carbon storage in the UK". *The Agile Initiative*, University of Oxford, UK. Available: **http://dx.doi.org/10.5287/ora-2r2onvvpk**

The Agile Initiative at the Oxford Martin School (funded by the Natural Environment Research Council) aims to transform how research responds to the needs of policymakers through timely, policy-oriented research Sprints that focus on critical environmental issues.

This document was produced by an Agile Initiative Sprint, addressing the question, "What do we need to know to safely store CO_2 beneath our shelf seas?" The writers aim to improve understanding of the environmental risks and opportunities associated with CO_2 storage in offshore reservoirs, to deliver new research, and to integrate existing knowledge from across research and policy areas, identifying gaps and areas requiring further research. This Sprint concluded in June 2024. This document was prepared by the Sprint researchers, and led by Millicent Sutton.

The writers would like to express thanks to the Agile Initiative engine room team, and to the reviewers: Mirte Boot, Stuart Jenkins, Steve Smith, Anupama Sen, Mike Kendall, and Myles Allen.

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Executive Summary

Scope

This brief focuses on the U.K. policy and regulatory framework and reforms available to the UK as it looks to scale-up the CCS industry effectively and begin safe geological CO_2 storage (GCS) in the UK offshore continental shelf (UKCS). The brief covers the current state of offshore CCS regulation and discusses opportunities available to streamline legislation, regulation and policy surrounding access to CO_2 storage on the UKCS, based on insights from diverse stakeholders regarding this regulation. We discuss the consequences of these findings for policy, industrial scale-up of geological storage, and the future direction of UK CCS policy and legislation. The UK has a developed regulatory environment for offshore GCS, but regulatory challenges remain. This is the central gap that this brief aims to address.

Background

Most IPCC scenarios require CCS with permanent sequestration of CO_2 in geologic formations (IPCC 2023). Global scenarios consistent with limiting warming to 1.5°C measured from 1990 baseline suggest a 1000-fold increase in CO_2 capture and storage deployment, compared to today's levels, to around 9 Gt CO_2 yr^{-1} by 2050[1]. The UK has 78.5 Gt CO_2 *theoretical* storage capacity on the UKCS, meaning there is ample supply of CO_2 storage space for the UK and its neighbours. The UK Climate Change Committee's balanced pathway projections indicate that the UK will need to capture and store 75-180 Mt CO_2 per year from fossil fuel sources, biomass sources and DAC at the time of Net-Zero[2], but there remain significant regulatory and financial hurdles to deployment on the scales required to achieve a 1.5°C-compatible UK mitigation trajectory.

Today, the UK does not yet have an operational storage project, but the new Labour Government remains committed to CCS development. False starts due to wavering support from previous Governments in 2005-2018[3] has led to the UK to fall behind other countries including Canada, USA, Norway, and Denmark. Given the Endurance storage site in the U.K. is being developed with FID expected before the end of the year, and the Government's proposal to license and support 30 Mt CO_2 yr^{-1} worth of storage projects by 2030[4]; there is an urgent need for evidence-based policy and regulation to facilitate the scale-up an industry critical to achieving climate goals.

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[1] Zhang, Y., Jackson, C., & Krevor, S. (2024). The feasibility of reaching gigatonne scale CO_2 storage by mid-century. Available at: https://www.researchsquare.com/article/rs-4011559/v1

[2] UK Climate Change Committee (2020) The 6th Carbon Budget: Greenhouse Gas Removals. Available at: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-GHG-removals.pdf

[3] House of Commons (2019). Business, Enerfy and Industrial Strategy Committee. Carbon Capture usage and Storage: third time lucky? Available at:

[4] DESNZ (2023) CCS Vision Statement. Available at: https://www.gov.uk/government/news/new-vision-to-create-competitive-carbon-capture-market-follows-unprecedented-20-billion-investment

Recommendations

Table 1 - Recommendations for Regulators, Policymakers, and Industry. Key: Red indicates difficult, slow or most urgent; orange indicates medium speed, ease or urgency; green indicates easy, fast or least urgent.

Recommendation	Audience	Rationale	Implementation	Speed	Ease	Urgency
Create system of integrated marine planning across different uses (e.g., carbon storage, offshore renewable infrastructure, fishing, marine protected areas, deep-sea mining and shipping)	Regulator and Crown Estate	Marine spatial planning is siloed from GCS considerations, with potential seabed licensing conflicts between offshore renewable infrastructure, seabed cables, fishing, trawling, deep-sea mining and GCS. Some of these risks are in the process of being addressed in the Crown Estate's Marine Route Map, but questions remain on the prioritisation in the of use of the marine space.	The Crown Estate should publish the decisions reached at the Marine Planning Forum. Then, DESNZ may use this consensus to design regulation for the marine planning system for all sectors using the marine space. This will prevent conflicts of use of the seabed.	Medium	Difficult	High
Consider how decommissioning of hydrocarbon infrastructure may be retrofitted for GCS	Regulator	Before hydrocarbon infrastructure gets decommissioned, the NSTA must consider the cross-over in regulation for hydrocarbon decommissioning and building the infrastructure for a GCS at the same site.	These obligations could form part of a new set of regulation aimed specifically at retrofitting oil and gas during the decommissioning phase for GCS, and regulation for decommissioning GCS. Amendments to the eligibility criteria in the hydrocarbon decommissioning regulation would allow for hydrocarbon infrastructure to be re-used for GCS.	Medium	Easy	High
Determine legal liability for CO_2 leakage and seismicity surrounding licence blocks	Regulator	Legal stakeholders have identified a lack of provision for liabilities arising from pressure communication amongst carbon storage licence blocks and between carbon storage and hydrocarbon licence blocks. Pressure fronts need to be carefully considered and managed to prevent leaks and infrastructure damage. Lack of clarity regarding these liabilities hinders further project developments.	Provisions for licencing and permitting are laid out in the Energy Act 2008 §C.3. An amendment, or a Henry VIII clause by the Minister of State, would clarify this uncertainty for project developers and projects from other industries in the vicinity of a GCS licence block.	Fast	Easy	High

Recommendation	Audience	Rationale	Implementation	Speed	Ease	Urgency
Clarify how the Levelling up and Regeneration Act 2023 should be implemented in relation to CCS projects and clusters	Legislator	The Levelling Up and Regeneration Act 2023 created significant planning uncertainty because it alters environmental impact assessments (EIAs) to Environmental Outcome Reports (EORs) and consolidates ministerial power to make final decisions for an infrastructure project like GCS. In practice, however, this has generated considerable confusion for project developers.	Legislators may wish to issue a statement of use, clarifying which ministers are responsible for signing off EORs, and which projects are eligible for special environmental exemptions.	Fast	Easy	Medium
Clarify transfer liabilities of CO_2 between operators along CCS value chain	Policymaker	This is needed so that fellow operators, and the insurance industry, can attribute risk between the different components of the value chain. In the current regulation there is no clear understanding of when CO_2 is counted as "delivered" into the storage reservoir. This has implications on the carbon credit system(s), and company's revenue stream from the UK/EU ETS.	Regulators may also consider multi-client MMV, where operators can pool resources to monitor adjacent fields and pipelines. Pooling resources this way can be a more cost-effective method of monitoring, and this may also standardise the data collection formats for regulators.	Fast	Medium	Medium
Create steady policy to support CCS/GCS developments over time	Policymaker	Robust, consistent policy, with adequate forward planning is seen as essential by industry representatives, and commentators, and yet, unaddressed in the regulation. Policy changes in the past have hampered the development of CCS in the UK (e.g., scrapping in 2015 of the £1bn fund dedicated towards CCS).	Implementation of steady policy is difficult as policy is determined by the politics of Ministers. One solution would be to make critical policy levers statutory, so it is more difficult to be amended in retrospect. Regulatory incentives such as storage capacity obligations (as in the EU Net Zero Industry Act) or actual removal and/or storage obligations (as in California's SB308 Bill) are also less susceptible to policy change than direct subsidies. UK regulators may wish to copy these models.	Slow	Difficult	Medium

Recommendation	Audience	Rationale	Implementation	Urgency	Ease	Speed
Clear post-closure monitoring obligations for leakage, induced seismicity for decommissioning GCS	Regulator	Regulators should clarify these obligations, and draw-up statutory regulations. This may provide a clear baseline for project developers so they may allocate necessary capital and provide certainty for future developments.	These obligations could form part of a new set of regulation aimed specifically for the decommissioning phase for GCS.	Low	Easy	Medium
Consider provision for cross-border reservoirs and liabilities between Norway-UK shared continental shelf	Regulator	Lawyers acting on behalf of industry operators have identified a lack of provision for liabilities related to pressure fronts extending beyond the UKCS, to the Norwegian Continental Shelf.	Remedying this is a matter for Ministers of State and their counterparts in the Norwegian Government. Options include bi-lateral agreement, and joint statements of intent.	Low	Difficult	Slow

List of Abbreviations

CCA	Climate Change Act 2008
CCS	Carbon capture and storage
CCUS	Carbon Capture Utilisation and Storage
CO_2	Carbon dioxide
DAC	Direct air capture
DESNZ	Department of Energy Security and Net Zero
EOR (1)	Environmental Outcome Report
EOR (2)	Enhanced Oil Recovery
ETS	Emissions Trading Scheme (UK or EU)
FID	Final Investment Decision
GCS	Geological carbon dioxide storage
GHG	Greenhouse gas
Gt CO_2 yr^{-1}	Gigatonne (10^{15}g) of carbon dioxide per year
IPCC	Intergovernmental Panel on Climate Change
NbS	Nature-based solutions
NCS	Norwegian Continental Shelf
NERC	Natural Environment Research Council
NEP	Northern Endurance Partnership
NPT	Non-pipeline transport
NSTA	North Sea Transition Authority
MMV	Measurement, monitoring and verification
Mt C	Megatonne (1012 g) of carbon
ONZ	Oxford Net Zero
T&S	Transport and Storage Codes
UKCS	U.K. Continental Shelf

Contents

Carbon Capture and Storage (CCS): a key decarbonisation tool globally and in the UK

The Intergovernmental Panel on Climate Change (IPCC) highlights that meeting climate targets in line with the Paris Agreement will necessitate both deep reductions in emissions, including the use of Carbon Capture and Storage (CCS), as well as carbon removal (CDR) to achieve Net-Zero[5] targets. CCS involves capturing emissions from industrial sources, transporting, and injecting CO_2 into underground geological formations (such as saline aquifers, depleted oil and gas wells, or reactive basalts).

When applied to fossil fuels, CCS is a tool for reducing emissions. When applied to fossil fuels, CCS is a tool for reducing emissions (the green section of the graph in Fig.1). When applied to sources of CO2 from biomass use or from directly from the air, CCS removes emissions that are already in the atmosphere (the blue section of the graph in Fig 1). In this sense, geological storage can contribute to both CDR and CCS. CDR is the 'net' and CCS is one part of the 'zero' in Net-Zero (see Fig.1).

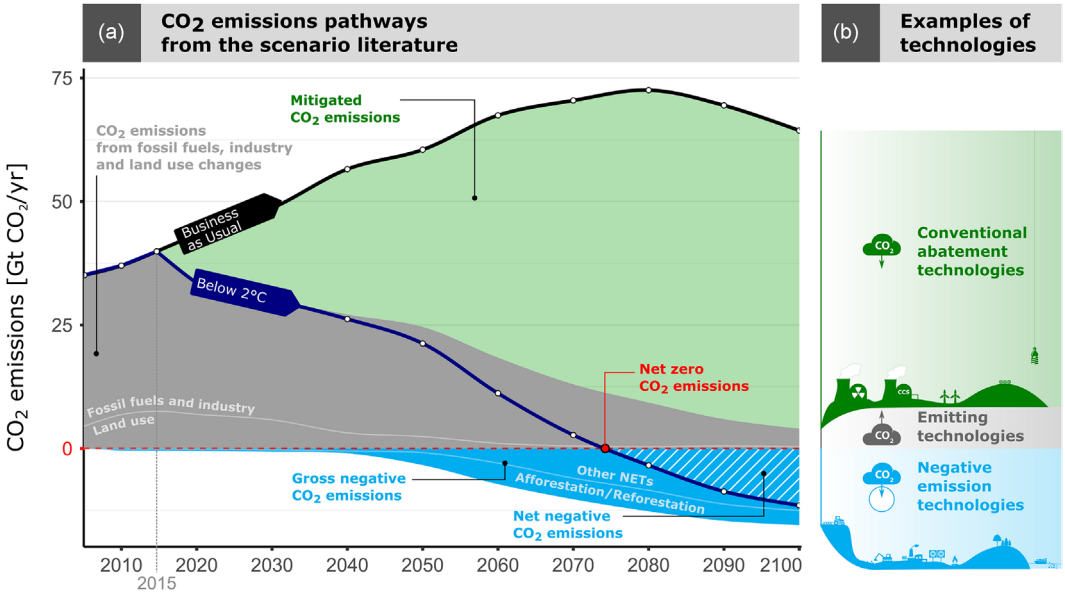

Figure 1 – This figure shows that geological storage is required for both the green and the blue proportions of the graph (Fuss et al 2018)[6].

[5] Geological net-zero is defined as 'any ongoing production of CO_2 from fossil-fuel sources is balanced by geological CO_2 disposal by 2050.' (Jenkins et al 2023).

[6] Fuss, S., Lamb, W. F., Callaghan, M. W., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., Garcia, W. de O., Hartmann, J., Khanna, T., Luderer, G., Nemet, G. F., Rogelj, J., Smith, P., Vicente, J. L. V., Wilcox, J., Dominguez, M. del M. Z., & Minx, J. C. (2018). Negative emissions—Part 2: Costs, potentials and side effects. Environmental Research Letters, 13(6), 063002. https://doi.org/10.1088/1748-9326/aabf9f

Almost all global modelled pathways that limit warming to 1.5°C (<50%) involve rapid and deep emissions reductions in all sectors[7] using CCS plus conventional reductions[8]. Yet, despite its critical role in climate mitigation, the CCS industry remains nascent around the world. Public support and R&D historically have been focused on the 'capture' segment of the value chain.[9] In contrast, the 'storage' element of the value chain, geological CO_2 storage (GCS) – has not received substantial attention. GCS is vital to both the CCS and CDR deployment as safe disposal of CO_2 into GCS sites is the component in the value chain which ultimately enables Net-Zero.

Historically, CO_2 has been injected into geological storage for enhanced oil recovery (EOR), rather than for climate purposes, partly because without supporting policies there are no economic incentives attached to CCS.[10] Recently, CCS has developed more rapidly. The driving factors include, but are not limited to, regulation, carbon taxation (e.g. Norway), tax incentives (e.g. US, Canada), and emission trading systems (e.g. EU). This has led to the co-development of transport and storage (T&S) infrastructure to safely dispose of the captured CO_2[11]. Faster developments are occurring in areas with a high potential for geological storage and where CCS can help decarbonise power and industrial sectors. The UK is one such place. Despite this, there remains a mismatch between capture project development and T&S infrastructure deployment in many jurisdictions, leading to stop-gap measures being used to guarantee capture projects have access to GCS reservoirs.[12]

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[7] Sectors such as cement and steel use fossil-carbon to produce materials which are used in the renewable energy sector, housebuilding and others. We cannot shut down these industries because they are essential to society, but they are high carbon emitters. Thus, they are called "hard-to-abate".

[8] IPCC (2022) Summary for Policymakers. IPCC Working Group 3 6th Assessment. Available at; **https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf**

[9] IEA (2023). CCUS policies and business models. Available at: **https://iea.blob.core.windows.net/assets/d0cb5c89-3bd4-4efd-8ef5-57dc327a02d6/CCUSPoliciesandBusinessModels.pdf**

[10] IEA (2024). CCUS projects database. Available at: **https://www.iea.org/data-and-statistics/data-product/ccus-projects-database**

[11] Global CCS Institute (2023). Global Status of CCS 2023: Scaling-Up through 2030. Available at: **https://www.globalccsinstitute.com/wp-content/uploads/2024/01/Global-Status-of-CCS-Report-1.pdf** (p.29)

[12] Evatt et al (2024). Assessment of the potential for an NETP "capacity market". Available at: **https://www.negemproject.eu/wp-content/uploads/2024/04/D-2.5-Assessment-of-the-potential-for-an-NETP-capacity-market.pdf**
DESNZ (2023) UK CCUS vision. Available at: **https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-a-vision-to-establish-a-competitive-market**
EU (2023). Net Zero Industry Act: Making the EU the home of clean technologies manufacturing and green jobs. Available at: **https://single-market-economy.ec.europa.eu/industry/sustainability/Net-Zero-industry-act_en**

The UK boasts a theoretical offshore storage capacity of 78.5 Gt CO_2 on the UK continental shelf (UKCS). This is more than 200 times its annual CO_2 (Scope 1&2) emissions, which were estimated at ~400 Mt CO_2 yr^{-1} in 2022[13]. This figure may be higher in the context of ongoing emissions reductions needed to reach Net-Zero in mid-century. This provides the UK with a potential long-term solution to store both CO_2 captured from the atmosphere by CDR technologies[14] *and* decarbonise emissions from hard-to-abate sectors[15], while leaving scope to offer CO_2 storage as a service to neighbouring jurisdictions.

The history of CCS in the UK spans two decades and includes three industry competitions and multiple government departments. From 2007-2011, and 2012-2015 the Government funded two CCS Demonstration competitions, but negotiations were terminated in 2011 and 2015[16]. In 2022, the UK Government developed business models to incentivise CCS deployment by different emitters (e.g., industry, energy-from-waste, power sector), including a dedicated transport & storage business model. Following this, the Government committed to £1bn for CCUS clusters and published its CCUS Vision in December 2023, which outlined a three-phased approach for the delivery of a long-term CCS sector. The first phase focuses on the delivery of capture projects supported by Contract-for-Difference mechanism, built around shore-side industrial clusters. T&S infrastructure is supported by separate subsidy mechanisms. They aim to transition towards a 'self-sustaining market' from 2035 onwards.[17] Complementing these developments, the UK also has a developed regulatory environment for offshore geological CO_2 storage. However, regulatory challenges remain. This is the central gap that this brief aims to address.

This research engaged with over 100 stakeholders, interviewed 23 participants, and convened a workshop with 65 participants from industry, government and academia to discuss evidence gaps and *status quo* of UK offshore GCS regulation. The brief is divided into three parts:

i. **Outlining the *status quo* and mapping the legal framework relevant for GCS** including an overview of the licensing and permitting processes and relevant departments involved (See Fig.3&4).

ii. **Discussing key themes and gaps** which were raised throughout this research. Our data engages with questions and regulatory challenges for the Endurance storage site in the southern North Sea, which is owned and managed by the Northern Endurance Partnership (NEP).

iii. **A conclusion with policy recommendations** which can enable an evidence-led discussion for GCS policymaking.

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[13] UK DESNZ (2024). 2022 Greenhouse Gas Emissions, Final Figures. Available at: https://assets.publishing.service.gov.uk/media/65c0d15863a23d0013c821e9/2022-final-greenhouse-gas-emissions-statistical-release.pdf

[14] i.e. CO_2 that is additional to what would otherwise be removed from the atmosphere by mitigation techniques. CDR technologies include BECCS, DACCS.

[15] i.e. those which cannot be otherwise mitigated through electrification, technology switching and/or energy efficiency enhancements.

[16] National Audit Office (2012). Department of Energy and Climate Change, Carbon Capture and Storage: Lessons from the competition for the UK's first demonstration. Available at:https://www.nao.org.uk/wp-content/uploads/2012/03/10121829es.pdf

[17] DESNZ (2023). Carbon capture, usage and storage: A vision to establish a competitive market.

(i) *Status quo* of UK offshore CCS regulations

Legal mapping: The UK Government has committed to reaching Net-Zero by 2050 pursuant to the 2018 Amendments to the Climate Change Act 2008. To achieve this target, the UK requires CCS (and in turn geological storage) to abate industrial emissions. According to the Climate Change Committee (CCC)'s UK 6th Carbon Budget, the UK will need to capture and store 75-180 Mt CO_2 from fossil fuel sources, biomass sources and Direct Air Capture (DAC) by 2050[18]. This promotes the need for low-carbon technologies – such as CCS – throughout energy and industrial sectors like power, steel, and cement. This has given rise to the current cluster sequencing approach, through which the government plans to utilise established industrial geographical 'clusters' to promote the sharing of CCS infrastructure, including the retrofitting of fossil-fuel platforms and pipes for offshore GCS.

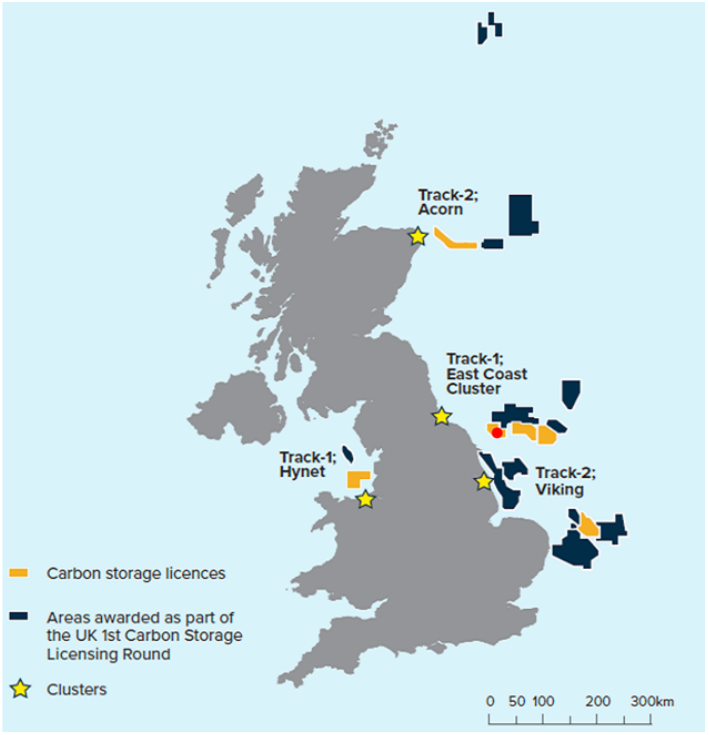

Figure 2 - Map of UK industrial clusters and geological storage sites. Red-dot indicates the Endurance Licence Block. Source: DESNZ CCUS Vision (2023).

Current UK regulation on CCS is centred around developing the first Track-1 clusters, HyNet and East Coast (Figure 1)[19]. The CCUS Vision includes a plan to expand to at least four other clusters, including the Track-2 clusters Viking CCS and Acorn (see Fig.2), with offshore GCS as the intended destination for the captured CO_2. These efforts will contribute to the UK's overall aim of capturing 20-30 Mt CO_2 of emissions per year by 2030 across the economy.

The offshore storage component of the CCS value chain is regulated by the North Sea Transition Authority (NSTA). This is pursuant to the Energy Act 2008 and the transposition to UK law of the EU CCS Directive (2009) which establishes a legal framework for the safe offshore geological storage of CO_2.

The NSTA regulates key components of sub-surface storage including measurement, monitoring, and verification (MMV), the storage complex, leakage events, and operator compliance. This is implemented using a range of regulatory powers granted by the Petroleum Act 1998, the Energy Act 2011, and Energy Act 2016[20]. These Acts confer responsibility onto the NSTA for environmental protection from leakage and CCS infrastructure while maximising resource-use and efficiency of the UKCS. Although the NSTA has overall authority, other regulatory bodies may be involved for specific issues like leakage or marine environmental protection (See Fig. 3 &4). The NSTA has oversight of both the onshore and offshore petroleum and the offshore carbon storage industry, and so has unique insight into managing potential conflicts of use of the UKCS.

[18] UK Climate Change Committee (2020) The 6th Carbon Budget: Greenhouse Gas Removals. Available at: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-GHG-removals.pdf

[19] As set out in the UK's Net Zero Strategy (2021) and Industrial Decarbonisation Strategy (2021).

[20] The Carbon Dioxide (Licensing etc.) Regulations 2010 (SI 2010/2221) transposed the EU CCS Directive (2009) into UK law.

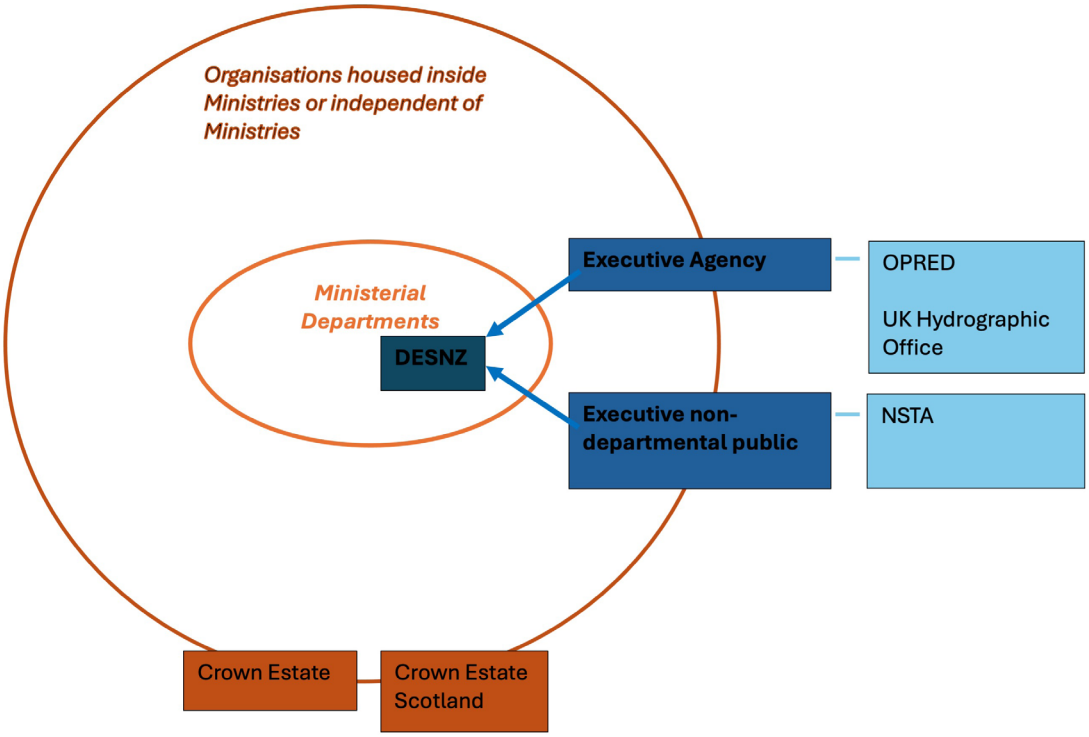

Figure 3 - Regulatory bodies involved with CO2 leakage in GCS licence blocks. (Self-drafted).

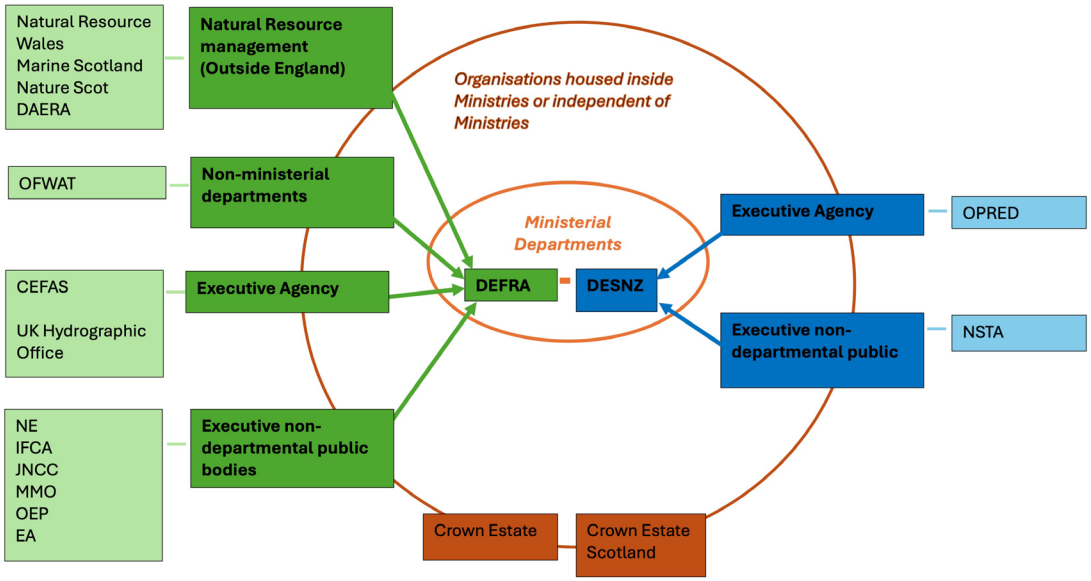

Figure 4 - Regulatory bodies involved with marine environmental protection in GCS licence blocks. (Self-drafted).

Licence granting process: The Department for Energy, Security and Net Zero (DESNZ) is responsible for creating policy for the CCS industry. The Minister of State for DESNZ has ultimate authority through powers granted through primary legislation (or the parent act and statutory instruments). Ministers of State for DESNZ can introduce secondary legislation, provided it is within their "granted powers" and consistent with primary legislation. DESNZ has oversight of the NSTA to execute the regulations and implement policy. Figure 5 illustrates the phases through which storage licences and permits are granted.

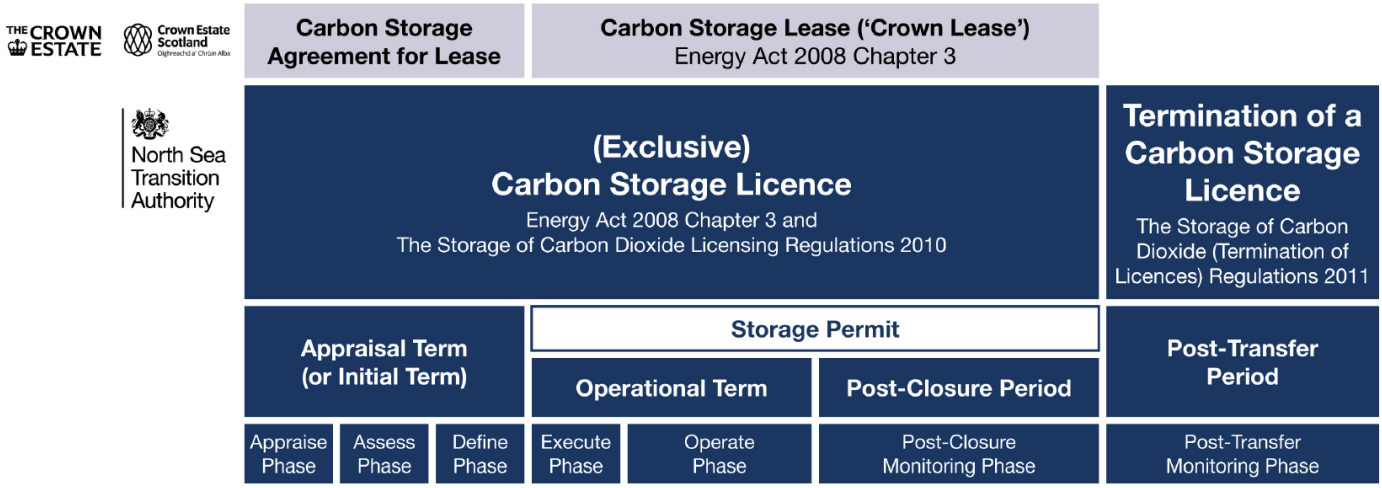

Figure 5: Phases of CO_2 storage licensing and permitting (NSTA, 2023)[21]

Developing a GCS project first involves applying for a storage licence. This involves financial and compliance checks and may take between 2-10 years. At its core, the issuance of a license is contingent on the NSTA deeming the operator as safe and responsible. While the licencing framework has statutory status, it is worth highlighting that the finer components of implementation are yet to work out in practice, as no UK GCS project is operational yet. As the GCS industry scales, the regulatory framework will be tested – (initially on the Endurance reservoir – see Fig.2) – meaning unforeseen challenges may require regulatory adjustments.

The second stage in storage development is securing a permit. (A permit applies only to a specific project which may span one or multiple wells within a single field, whereas a licence can span multiple permits i.e. projects.)[22] Permitting guidance documents have recently been published by the NSTA (2024)[23], but have not yet been operationalised, and so this may also require amending as the industry scales.

The third stage involves complying with other legislation and regulation which do not directly govern GCS but govern adjacent impacts from CCS developments.[24] For example, the UK Energy Act 2023 is crucial to development as it rectifies gaps in previous legislation, some of which were caused by the withdrawal of the UK from the European Union. It aims to create a comprehensive GCS legislative regime. However, due to amendments in the Commons, the Act does not address all practical concerns like decommissioning, or liabilities associated with a GCS licence block.[25] The 2023 Act reflects the increased ambition in climate policy targets set by the UK Government. For the CCS industry, the 2023 Act functions in two key ways:

1. Assigns Ofgem as the economic regulator for GCS;
2. Improves the reporting of carbon storage license holders.

Moreover, this 2023 Act works in synchronicity with the Climate Change Act (CCA) 2008 which provides a long-term framework for climate change policy in the UK and renders UK emissions reduction targets legally binding. Initially, the Act specified at least an 80% reduction in GHG emissions by 2050 below 1990 levels[26]. However, this was amended in 2019[27] to at least a 100% reduction in GHG by 2050. This Act is significant because it binds all industries (including the GCS industry) to net zero[28].

[21] NSTA (2023). Guidance on applications for a carbon storage permit. V2, published November 2023. Available at: https://www.nstauthority.co.uk/media/oxuhiqtb/guidance-on-applications-for-a-carbon-storage-permit.pdf

[22] 2010 Regulations

[23] NSTA (2023). As above.

[24] See Appendix 1 for a list of the relevant legislation and regulation applicable to a GCS project.

[25] Anonymous participant in the research interviews

[26] (Climate Change Act, 2008)

[27] Climate Change Act 2008 2050 Target Amendment Order 2019 (SI 2019/1056)

[28] Greenberg, Daniel (2024) Overview – Climate Change Act 2008. Westlaw, Reuters.

(ii) What gaps exist?

Several participants in this study highlighted that UK CCS legislation is considered a global "gold standard". However, our research and our research participants have identified several existing and potential future challenges which need addressing to clarify the landscape for UK CCS deployment. We classify these under three overarching themes: 1) Licencing, Permitting and liabilities, 2) Financial and economic policy, and 3) CCS and decarbonisation policy.

Theme 1: Licencing, Permitting, and Liabilities

This study identifies systemic hurdles in the permitting and licencing process. Current licencing and permitting regulations are being developed around the Endurance project. This indicates that regulations may be partially bespoke for individual clusters as each cluster has unique operating conditions (i.e. geology, proximity to T&S infrastructure), thus potentially requiring different levers in regulations and regulatory agencies, particularly where there are biodiversity or co-siting concerns. The UK Government has introduced a comprehensive licencing process for GCS. Permitting frameworks are currently undergoing consultation. Current proposals indicate that within each cluster, the relevant regulatory agencies (see Fig.3,4,5) will tailor and approve permits on a case-by-case basis. A case-by-case approach contains the risk that granted carbon licences and individual permits do not reach operational maturity, as individual permits from NSTA may be insufficient for a project's success. A project may require permits from other regulatory agencies, which highlights the complexity of navigating a bespoke multi-agency process for individual permits.

The process to streamline projects, though, is unlikely to work because each government agency oversees many other uses of the UKCS, and none are dedicated storage specialists[29].

One of the key conditions for granting a permit is likely to be data transparency. Publicly available data that stakeholders can access, in a standardised format, is key for the regulator to improve data management, promote open-access and accelerate CCS projects. By driving collaboration and data learning across jurisdictions, projects can become more economical. Currently, there is a lack of dynamic real-time data and transparency across the industry to allow for independent verification. To improve transparency, companies could provide open-access data regarding seismicity, pressure management, structural trapping and environmental impacts. These data categories would not infringe on companies' confidential data and intellectual property, while increasing learning across the sector and fuelling industry expansion.

Additionally, effective legislation requires balancing interests of all relevant stakeholders. For instance, some domestic UK stakeholders are campaigning for alignment with the EU CCS Directive to enable non-pipeline transport (NPT) in the UK[30]. UK legislation may consider balancing their interests with political priorities on EU policy. UK legislation has not yet aligned with the CCS Directive, meaning that the UK is not yet creating frameworks – or planning mechanisms – to enable the transport of CO_2 to the UK for storage. Similarly, the UK must update its CCS Network Codes and legislation to allow for NPT and implementation of the amendments to the London Protocol[31], so the UK can import CO_2 as either a "waste" or a "commodity" across international borders and maximise use of UKCS pore-space.[32]

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[29] Anonymous participant from research interview 2024.

[30] CCSA (2024). Achieving a European market for CO_2 transport by ship. Available at: https://www.ccsassociation.org/resources/download?id=4787

[31] The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972) or "London Protocol" for short, prevents dumping of waste and marine pollution. (International Maritime Organisation IMO). More information available at: https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx

[32] Ihejirika, N. (2024). Potential regulatory frameworks for cross-border CO_2 transport between the EU and UK. Oxford Institute for Energy Studies, Insight 152, Oxford, UK.

Offshore GCS will be contingent on robust measuring, monitoring, and verification (MMV).[33] UK regulators[34] require stringent (and likely costly) MMV to ensure public trust remains high and there is a high standard of environmental protection. This must be balanced against an operator needing to minimise costs. Flexibility in monitoring requirements, and a diversity of MMV options in regulation, would allow for fit-for-purpose monitoring which satisfies all relevant stakeholders.

If MMV requirements are not met, certain penalties may be imposed on operators. These financial penalties and physical liabilities may potentially be significant. Currently, the Government acts as an insurer of last resort and the underwriter of all storage related risks[35],[36]. GCS operators do face liabilities however, including leakage and pressure communication between reservoirs. In very rare cases, liabilities may arise from pressure communication within the GCS license block. These are particularly difficult as pressure from within a specific GCS licence block may cause events such as CO_2 leakage from abandoned wells outside the licence block or disrupt oil production in a neighbouring hydrocarbon licence block. If an operator encounters these forms of liability, there is a lack of clarity over which operator is responsible for remedying the incident i.e. the operator which caused the incident, or the operator licence block in which the incident occurred. Companies are responsible for the reservoir up to 20 years post-closure, beyond which the Government takes responsibility over the well. However, post-closure, the CO_2 is likely to remain indefinitely in the reservoir, but there are no provisions mandating companies to deposit all reservoir information into a central Government repository. Thus, if there is an incident in the future, there will not be a record of the CO_2 plume depth and volume. In contrast, nuclear decommissioning mandates a central data repository of the nuclear waste material. A similar central data repository or management system for CO_2 waste may prevent future incidents, prevent closed wells remaining hidden on company books, and ensure the records are not lost over time.

Finally, there are concerns around the decommissioning of fossil-fuel infrastructure and subsequent retrofitting for GCS sites. Currently, hydrocarbon decommissioning and retrofit for CO_2 storage sites are not being considered by the Government in the financial regulation surrounding hydrocarbon decommissioning funding. Much of the North Sea oil and gas infrastructure is approaching the decommissioning stage, presenting an opportunity to retrofit hydrocarbon infrastructure for GCS. Hydrocarbon licences mandate operators, during the operational phase of a licence, to place capital into a fund for decommissioning, but there are no eligibility requirements to use this money for GCS retrofitting instead. This could be achieved through a 'screening' of sites due to be decommissioned. The screening could include certain eligibility requirements – both financial and geophysical - like divesting company profits into CCS, or requiring 4D seismic surveys of well-infrastructure. This could determine the site's suitability for carbon storage, allowing for the re-purposing oil and gas infrastructure in hydrocarbon decommissioning legislation. Cross-sectoral thinking and collaboration will be essential to ensuring that pore-space resources are used most efficiently.

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[33] The monitoring and reporting regulations (MRV - retained EU Law but amended under the Order as well) Articles 40-49 and Annex IV (sections 21-23) are key areas for CCS. This also requires independent verification (AVR).

[34] Laid out in the 2010 Regulations

[35] HM Treasury (2020). Government as insurer of last resort: managing contingent liabilities in the public sector. Available at: https://assets.publishing.service.gov.uk/media/5e67c54e86650c727b2f46d6/06022020_Government_as_Insurer_of_Last_Resort_report__Final_clean_.pdf

[36] Clewley, T. (2017). Carbon Capture and Storage Legal frameworks. Westlaw, Reuters.

Theme 2: Financial and Economic policy

The UK has one of the largest geological storage resources globally, so there is opportunity for a large GCS industry to generate significant revenues by offering 'storage as a service' to international partners. To aid this, the UK Government has three levers at its disposal to kickstart GCS in the UKCS. These include: 1) subsidies for clusters and direct procurement; 2), emitter-targeted policies driving demand (ETS/carbon pricing); and 3) standard-setting and regulation for low-carbon products. These mechanisms, though, can only go so far towards developing the industry for a self-sustaining future. This paper highlights three barriers to creating a self-sufficient GCS sector.

Firstly, there is a cross-chain risk that is insufficiently addressed in current business models. An important characteristic of the UK CCS landscape is the adoption of 'split-chain' business models where the capture, transport, and storage components of the value chain are financially separated. This model supports capture of CO_2 at point-sources by emitters through industrial contracts that act as Contracts-for-Difference, where the UK ETS price acts as the 'reference' price and the cost of abatement as the 'strike' price, with the difference subsidised by government. The Transport and Storage Regulatory Investment model (TRI) supports CO_2 transport and storage infrastructure development by providing financial assistance to T&S companies (T&SCo) for the initial infrastructure costs[37]. Both these models are designed to reduce cross-chain risks but may in practice pass risks along the chain when not enough CO_2 is captured to give investor confidence for T&S operations – otherwise referred to as the 'chicken-and-egg' paradox. This may result in storage sites not being available in time to store CO_2 which is successfully captured at source. The UK's established TRI model tries to hedge against this risk by providing a continued revenue stream for T&SCo (from a dedicated 'Government Support Package') which ensures GCS operators recoup costs even if CO_2 does not flow through pipelines.

Secondly, the role of the insurance industry in GCS is nascent and is holding back rapid development. GCS operators still face hefty upfront capital costs and may face many years of waiting to receive the necessary storage licence and permit(s). This means some projects may not come to fruition. Here, insurance could act as a derisking mechanism, and play an important role in collateralising risk, finance, and project debt. The insurance industry currently only offers products which can protect physical infrastructure – and the potential stream of carbon credits which may be produced from a project – but in the UK there are no products (yet) providing long-term protection for a reservoir. Moreover, typical insurance contracts tend to cover a 12- to 18-month period, which is incompatible with projects requiring insurance for ±25 years. Recent policy aiming at addressing this discrepancy designates the Government as the "insurer of last resort", using similar frameworks to "FloodRe" in the Government's flood protection scheme. While this may help alleviate the problem, the insurance industry's involvement with GCS is important for de-risking projects, and may offer reassurance to investors, while hastening the scale-up of the GCS industry.

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[37] DESNZ (2023). Carbon Capture Utilisation and storage transport and storage business model. Consultation on revenue support regulations… Available at: https://assets.publishing.service.gov.uk/media/64fb252b572780000d251827/ccus-ts-rsa-counterparty-direction-consultation.pdf

The third significant barrier to creating a self-sustaining GCS industry is uncertainty surrounding project finances beyond 2035. The previous UK Government agreed to financially support the industry from 2022-2035, but support is expected to taper off from 2030 onwards. This carries risks, especially if carbon prices under the UK-ETS are potentially too low[38] or too volatile to provide a reliable alternative source of financing on their own.[39] While some argue carbon taxation could fill this gap, others point out this mechanism is similarly unsuitable, because it incentivises emission reductions at source but does not directly incentivise storage. This underscores that the CCS industry is being developed due to Government funding, *not solely* market mechanisms.

However, UK taxpayers are bearing most of the costs of the GCS industry[40]. Given this, the UK Government has two options. First, policymakers may wish to create a publicly owned GCS company – like GB Energy for the Energy sector – where the taxpayer bears the costs but receives only limited guarantees for the climate mitigation benefits they are paying for. In the current system taxpayers are subsidising hydrocarbon companies but have only limited control over the climate benefits (since the CCS subsidy caries no conditions on hydrocarbon production). The second option is to remove the subsidies to fossil-fuel companies for GCS, and the Government could legally oblige hydrocarbon companies to pay the costs of GCS. Indeed, in the long-term, this may be in the financial interests of fossil-fuel companies as the decarbonisation of the economy accelerates. In this way, the Government may maximise economic efficiency for the public purse, ensure consumers receive climate benefits of CCS at a fair cost, and reimagine an industry where supply-side mandates oblige polluters to pay to sequester the direct and indirect emissions from their operations[41]. In this way, the "polluter pays" principle would drive future market management with the hydrocarbon industry more directly incentivised to contribute to the GCS market in a way that incentivises cost reductions and reconceptualises the way we value emissions and CCS as "cleaning up waste"[42].

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[38] UK-ETS price of £45 as of June 25, 2024. Source: **www.carboncredits.com**

[39] The ETS requirements for CCS are underpinned under the ETS legislation (SI 2020/1265 as amended)

[40] BEIS (2018) Industrial Carbon Capture Business Models. Available at: **https://assets.publishing.service.gov.uk/media/5bfc26a440f0b65b1a0916ee/BEIS_CCS_business_models.pdf**

[41] Jenkins, S., Mitchell-Larson, E., Ives, M. C., Haszeldine, S., & Allen, M. (2021). Upstream decarbonization through a carbon takeback obligation: An affordable backstop climate policy. *Joule, 5*(11), 2777–2796. **https://doi.org/10.1016/j.joule.2021.10.012**

[42] Buck, H. J. (2020). Should carbon removal be treated as waste management? Lessons from the cultural history of waste. *Interface Focus, 10*(5), 20200010. **https://doi.org/10.1098/rsfs.2020.0010**

Theme 3: CCS and decarbonisation policy

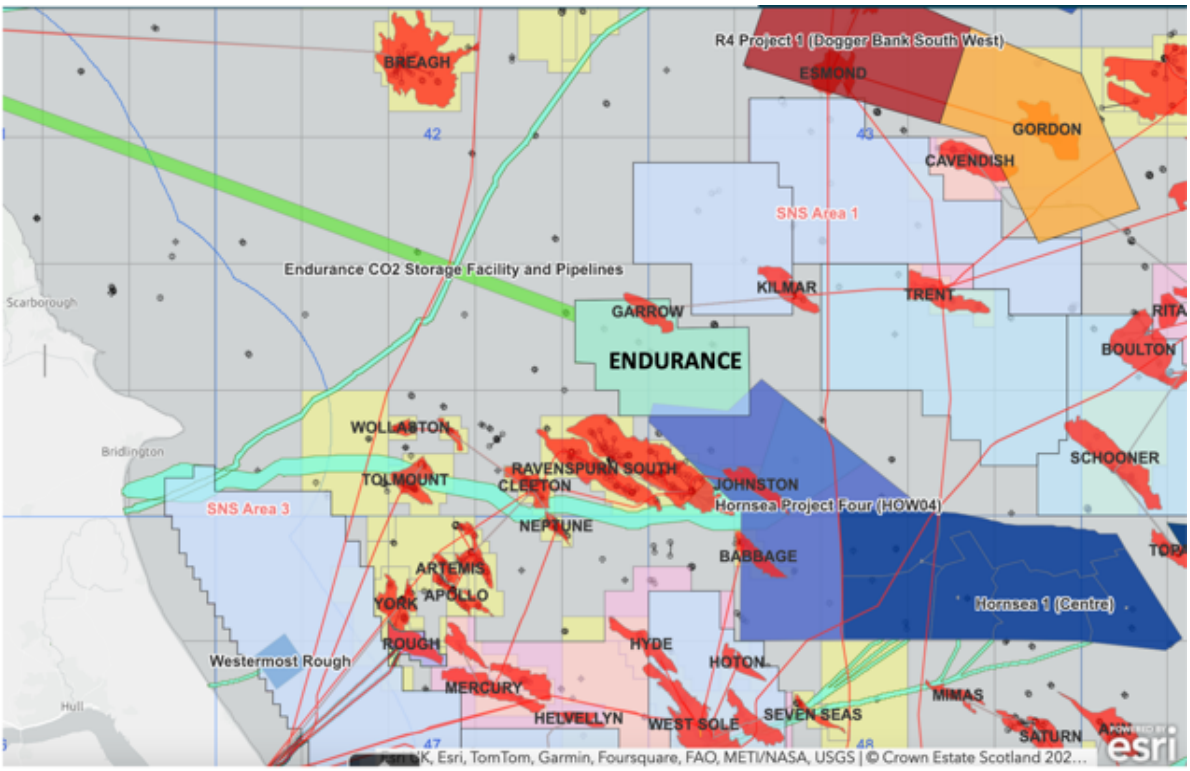

Figure 6 - UKCS Lease Agreement maps. Teal means carbon storage licences, dark blue means offshore wind farms either active or under construction, pale blue means carbon dioxide appraisal licences, dark orange means gas field, red lines mean gas pipeline, yellow means licenced oil field, pink means carbon storage areas offered for application by NSTA (NSTA 2024).[43]

Integrated marine planning

A significant number of offshore areas identified for GCS are co-located under or near areas identified for renewable energy development, or other marine uses. Although UK CCS policy encourages integration across different geographical 'clusters' whereby power and industrial sectors jointly decarbonise, Fig.6 illustrates that it is critical to view CCS holistically within wider decarbonisation policies and technologies.

Thus, following the Crown Estate's co-locating storage with renewables may make the best use of resources and utilise onshore capture/transport and offshore storage sites more efficiently.Co-location may require assessment of related risks in health and safety regulations, to ensure that subsurface pore-space is maximised without risking damage to offshore wind turbines, or other marine uses like fishing or shipping. UK policy must also allow for integration across international jurisdictions.

[43] NSTA (2024). UKCS Lease Agreement map. Available at: https://www.arcgis.com/apps/webappviewer/index.html?id=cb3474a78df24139b1651908ff8c8975

For instance, if the UK implements the (updated) London Protocol, it will allow for shipping or non-pipeline transport of CO_2 across international borders. To ensure this can go ahead, marine spatial planning (using the allocation frameworks in place from the Marine and Coastal Access Act 2009[44]) is required to designate marine space to different technologies and uses. This allocation will help to plan safe transport routes for CO_2 shipping and ensure that there are no conflicts of use between technologies (vis-á-vis seabed licencing conflict between Ørsted and Northern Endurance Partnership) and designate space for other technologies essential to the green transition.

Co-ordination of CO_2 injection

There are risks in the lack of standardisation of CO_2 purity along the carbon capture and storage value-chain and across sectors and jurisdictions. Unless it is regulated, different sectors are likely to produce different grades of CO_2 purity. Higher levels of impurities in CO_2 stream can cause corrosion in pipes or other forms of infrastructure damage and may affect injectivity rates. For this reason, regulators must ensure standardisation to prevent different grades of CO_2 purity being stored at the same site. To prevent this, policymakers may consider a CO_2 allocation and distribution strategy of different grades of CO_2 purity whereby certain reservoirs are designated for specific industries producing certain purities of CO_2. This strategy may also allow the Government to prioritise subsurface pore-space for industries with the highest grade of CO_2 and those most essential for the green transition.

Moreover, even though the clustering approach of UK policy has helped kickstart the CCS industry, it may be preventing the industry from scaling up fast enough[45]. This is for three main reasons. Firstly, there is a risk that the bundling of industrial sites into clusters creates technological lock-ins and favours pipeline transport rather than NPT. Secondly, the sector-specific approach taken increases the complexity of the system, so as the GCS industry expands it is prone to remain in sector-specific silos. Policymakers should therefore consider building in policy levers for unbundling clusters as the industry expands, i.e. extending the CCS industry to new sectors and beyond the original clusters to industrial sites that are outside clusters. Thirdly, the absence of a time limit on derogation of licences by the regulator, may be contributing to investment uncertainty. These factors, combined with a relatively long timeline for licence site appraisal (4-8 years), increases the likelihood of CCS not scaling quickly enough to meet the UK's 2050 Net Zero commitments. Policymakers must consider the implications of such a time delay on GCS scale-up. For example, the 2030 UK storage targets of 20-30 Mt CO_2 yr^{-1} [46] is already less than the growth rate required for 1.5°C[47] and meeting net zero.

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[44] Owen, Daniel. (2014) Overview - Marine Spatial Planning. Westlaw, Reuters.

[45] Department for Energy Security and Net Zero. (2024). CCUS Non-pipeline transport, and cross-border CO_2 networks – call for evidence. UK Government consultation. Available at: https://www.gov.uk/government/calls-for-evidence/carbon-capture-usage-and-storage-ccus-non-pipeline-transport-and-cross-border-co2-networks/ccus-non-pipeline-transport-and-cross-border-co2-networks-call-for-evidence

[46] UK Committee on Climate Change. (2019). Net Zero, The UK's contribution to stopping global warming. Available at: https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[47] Zhang, Y., Jackson, C., & Krevor, S. (2024). The feasibility of reaching gigatonne scale CO_2 storage by mid-century. Available at: https://www.researchsquare.com/article/rs-4011559/v1

It is essential for policymakers to prepare for a range of scenarios and communicate their preparations. Communicating UK progress on CCS, from historical precedents, is key to spotlight and benchmark progress, acknowledge which future pathways are likely more feasible and adjust storage targets accordingly.

Learnings from other jurisdictions

Of course, this scale-up challenge is not specific to the UK – the expansion rate of CCS and CDR infrastructure is a global barrier to achieving Net-Zero. Therefore, there are three key policy lessons which can be learned from other jurisdictions, particularly from the EU. Firstly, the EU has implemented ISO CO_2 purity standards which ensure standardisation across industries, grading of carbon storage units and associated credits, and protect infrastructure from corrosion due to impurities. If the UK were to align with the EU on this issue, it would complement the UK's ambitions to eventually store non-UK CO_2 in the UKCS and could help create the regulatory framework to do so. Secondly, the EU provides a key legislative framework in Article 18 of the EU NZIA. The EU hereby tackles the 'chicken and egg' problem highlighted above, in which there is a failure to build GCS at the correct rate to support capture projects, by implementing a supply-side GCS capacity mandate. This sets a precedent, meaning the UK may wish to adopt a similar solution. The third learning relates to business models and markets.

The EU has several mechanisms in place to stabilise the ETS market, meaning the UK may consider stronger links between the UK-ETS and the EU-ETS. This may help stabilise volatility and catch spill-over and network effects from countries with more financial resources dedicated towards CCS. The fourth learning relates to public ownership of GCS companies. In Denmark, the Danish Government set up a subsidiary company called Nordsøfonden, through which the Danish Government asserts 20% ownership of licence blocks.

This system is designed so 'state co-ownership ensures that society as a whole benefits from CO_2 storage"[48] and any profits are ploughed back into the industry to encourage further scale-up. Thus, while the "UK's regulatory regime is considered the global gold standard" (as noted by many of this study's participants), the UK may consider drawing from these best practices and adapting them for the UK context.

CCS as a "back-stop" solution

Finally, it is important to re-assert that CCS is designed to be a 'backstop' solution for residual emissions from hard-to-abate sectors which, proportionally, only represent a small fraction of total UK emissions[49]. To this extent, CCS must continue to be considered as one option among many other climate solutions that will be necessary to decarbonise the UK. Thus, it is essential for DESNZ to be able to plan for a range of scenarios, options and technologies which can be utilised up to 2050, depending on which climate, economic, and/or political scenario prevails.

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[48] Danish Energy Agency. (n.d.) Licences for exploration and storage of CO_2 including environmental consultation rounds. Available at: https://ens.dk/en/our-responsibilities/ccs-carbon-capture-and-storage/licenses-exploration-and-storage-co2-including

[49] Smith, H. B., Vaughan, N. E., & Forster, J. (2024). Residual emissions in long-term national climate strategies show limited climate ambition. *One Earth, 7*(5), 867–884. https://doi.org/10.1016/j.oneear.2024.04.009

One way of retaining CCS as a 'backstop' option is by conceptualising storage as a "scarce good", "resource in fixed supply" and "waste disposal". This may shift the dialogue on how we value and cost CO_2 emissions. Furthermore, if the market remains the primary mode of delivery of geological storage, it is important to ensure that the cost of the damage from CO_2 emissions is priced into a product, rather than as a negative externality. Other options or ensuring CCS remains a back-stop solution may include regulation to separate the fossil fuel industry from the storage industry (as has been done in Denmark)[50]. This financial regulation would function to ringfence flows of revenue from CCS to prevent (accidental) cross-subsidisation of the fossil fuel industry from CCS profits or subsidies. This would ensure that fossil fuel companies transition to becoming clean energy companies. In this way, regulation separates the components of the fossil fuel industry (knowledge and expertise in the use of the sub-surface) which are essential to a nascent CCS industry. A consideration of these type of policies is essential to improve public trust in CCS, as well as alter the perception that the green transition equates to de-industrialisation[51].

(iii) Concluding remarks

This brief has focused on the policy, regulation, and legislation required to kickstart the CCS industry and begin safe geological CO_2 storage in the UKCS and made recommendations (see *Table 1*) based on the evidence gaps identified. The brief summarises recent UK regulatory developments for GCS and highlights the importance of legislative frameworks to scale up geological storage to achieve Net Zero. Aided by a comprehensive set of policy support mechanisms, the UK has made considerable progress towards creating a GCS industry and aims to be a global leader in the technology's deployment. Global 'Net-Zero cannot be achieved unless everyone moves towards it; to this extent, the UK can play a key role in facilitating transfer of skills, technology, and resources to enable other countries to meet their climate commitments.

This research identified gaps in policy and governance for operationalising offshore GCS in the UK, highlighting the potential for the UK to undershoot national 2030 storage targets. These gaps are in the licencing and permitting regulations, the economic and financial policy, and the UK decarbonisation policy. Addressing these gaps will ensure that CCS remains a bridging technology to help societies move from a high- to low-emissions economy, complementing – rather than replacing – efforts to accelerate the deployment of zero-carbon energy sources and CDR solutions in parallel to the on-going phase-out of fossil fuels from the energy mix.

Looking ahead, it is expected that Northern Endurance Partnership (NEP) will take FID before the end of 2024. The UK is expected to continue developing a dynamic regulatory, legislative, and investment policy environment. We hope our analysis and recommendations will support these efforts.

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[50] Danish Energy Agency. (n.d.) Licences for exploration and storage of CO_2 including environmental consultation rounds. Available at: https://ens.dk/en/our-responsibilities/ccs-carbon-capture-and-storage/licenses-exploration-and-storage-co2-including

[51] Thomas, G., Cherry, C., Groves, C., Henwood, K., Pidgeon, N., & Roberts, E. (2022). "It's not a very certain future": Emotion and infrastructure change in an industrial town. *Geoforum, 132*, 81–91. https://doi.org/10.1016/j.geoforum.2022.04.003

Appendix

The following legislative body governs the entire U.K. CCS industry (not just GCS) (Clewley 2021).

Primary legislation

- Petroleum Act 1998
- Energy Act 2008
- Energy Act 2010
- Energy Act 2011
- Energy Act 2013

Subordinate legislation

- Energy Act 2008 (Consequential Modifications) (Offshore Environmental Protection) Order 2010/1513
- Storage of Carbon Dioxide (Licensing etc.) Regulations 2010/2221
- Storage of Carbon Dioxide (Inspections etc.) Regulations 2012/461
- Storage of Carbon Dioxide (Termination of Licences) Regulations 2011/1483
- Storage of Carbon Dioxide (Access to Infrastructure) Regulations 2011/2305
- Carbon Capture Readiness (Electricity Generating Stations) Regulations 2013/2696

Adjacent legislation with implications for CCS/GCS

- Energy Act 2023
- Levelling-Up and Regeneration Act 2023
- EU Revocation Act 2023
- Offshore Petroleum Licencing Bill 2024

Disclaimer: Applicable legislation is correct as of 30th June 2024.

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The Agile Initiative is supported by the Natural Environment Research Council as part of the Changing the Environment Programme – NERC grant reference number NE/W004976/1.

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