UNIVERSITY OF LEEDS

Priestley Centre for Climate Futures

Carbon capture and storage in the UK

Deployment requirements and risks

Elliott Johnson, Oliver Broad and Paul Brockway

December 2025

Executive Summary

This report examines the UK's reliance on carbon capture and storage (CCS) technologies in achieving Net Zero emissions by 2050, assessing whether the necessary technological, policy, and market developments can occur rapidly enough to meet national targets.

The Climate Change Committee (CCC) maintains that no credible pathway to Net Zero exists without CCS, projecting a need for approximately 73 $MtCO_2$ per year of combined mitigation and removal capacity by mid-century.

CCS encompasses both mitigation technologies that capture CO_2 from industrial and energy processes and removal technologies, such as bioenergy with CCS (BECCS) and direct air capture with storage (DACCS), that can result in net negative emissions. These engineered solutions are crucial for addressing residual emissions from hard-to-decarbonise sectors and large-scale deployment is expected. Current projects under the government's cluster sequencing strategy are projected to deliver just 5–10 $MtCO_2$ in carbon dioxide capture annually by 2030, which falls short of the CCC's 7th Carbon Budget pathway requirements of 13 $MtCO_2$.

Technological immaturity, high capital intensity, and historical policy inconsistency have constrained progress to date.

Despite a renewed commitment from the Labour government, including £21.7 billion of support for industrial clusters, the UK does not have an operational CCS facility. Historical failure rates for CCS projects globally are as high as 82%, suggesting significant delivery risk. Even under optimistic assumptions, planned CCS capacity may fall well below required levels unless failure rates are halved, and early projects achieve strong "learning-by-doing" effects, which may not be possible in cases of CCS being retrofitted onto existing fossil fuel infrastructure, which will be site-specific.

Under current plans, CCS deployment would need compound annual growth rates of up to 75% in its early years. Comparisons with past low carbon infrastructure rollouts - such as nuclear power - indicate that this pace is challenging, but potentially achievable if policy support and investor confidence remain strong. However, delays or mismatches between carbon capture and transport-and-storage infrastructure could undermine market integrity and lead to stranded assets.

To address some of these risks, this report recommends that the current political and financial support is sustained, with deployment focussed in sectors without viable alternatives, greater flexibility in cluster decarbonisation and the integration of Carbon Removal Obligations into the current regulatory framework to reduce risk. Public acceptance and ethical governance will be essential, ensuring CCS complements, rather than displaces, rapid and near-term emissions reductions – avoiding mitigation deterrence. While momentum is growing, substantial uncertainty remains as to whether CCS technologies can be deployed at the required scale and pace to meet the UK's 2050 Net Zero goal.

1. Introduction

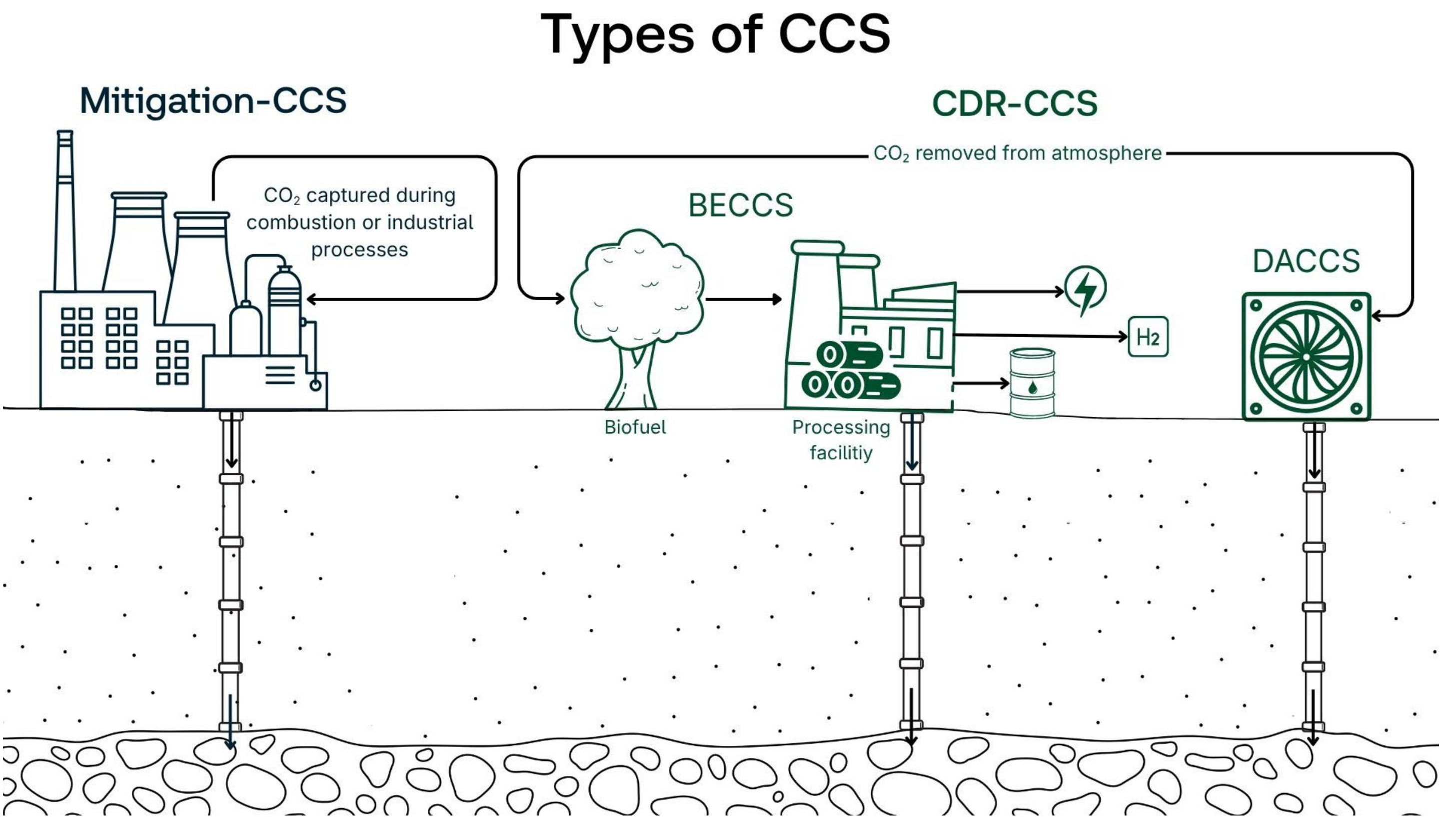
1.1. What is carbon capture and storage?

Carbon capture and storage (CCS), a broad set of technology-based practices that describe different ways of capturing and securely storing carbon dioxide (CO_2), represent important decarbonisation options that have become almost ubiquitous across mitigation scenarios at both national and global scales. In its latest advice to government, the UK's Climate Change Committee declared that they "cannot see a route to Net Zero [in the UK] that does not include CCS" (Climate Change Committee, 2025a, p. 14). While they are clear that these technologies cannot substitute for significant emissions reductions, they are "part of all modelled scenarios that limit global warming to 2°C or lower by 2100" (IPCC, 2022a).

For the purposes of this report, we divide the CCS family of approaches (also referred to as "engineered solutions") into two different groups: emissions mitigation options with CCS (Mit-CCS) and carbon dioxide removal technologies with CCS (CDR-CCS). First, Mit-CCS captures and separates CO_2 from the combustion of, or processing of, fossil fuels. These Mit-CCS options thus reduce the amount of CO_2 released into the atmosphere through continued fossil fuel use for energy production (e.g. electricity, or hydrogen), or in industrial processes such as cement production.

Second, CDR-CCS involve technology chains designed to capture and store atmospheric CO_2. These options are also referred to as Negative Emission Technologies (NETs) to describe their ability to deliver net CO_2 removal from the atmosphere over their full supply chain. The two most prominent CDR-CCS concepts are bioenergy with carbon capture and storage (BECCS) and direct air capture and storage (DACCS). BECCS describes a set of technologies that involve using energy crops, forest and agricultural residues to produce useful energy vectors alongside a stream of captured CO_2. The CO_2 is captured from the production or combustion processes involved in e.g. converting biomass to hydrogen or burning it for power. Similarly, utilising commercial and consumer waste – Energy from Waste (EfW) – to produce electricity or heat with CCS can reduce emissions or even result in negative emissions if a high enough proportion of biogenic waste is utilised. Conversely, DACCS describes the process of capturing CO_2 directly from the atmosphere using solid or liquid sorbent materials, but uses significant amounts of energy to extract CO_2 from ambient air.

Figure 1: Graphical representation of the different types of CCS processes.



Distinguishing between Mit-CCS and CDR-CCS, and, for CDR, between BECCS and DACCS, is important. First, mitigation options continue to add small amounts of new fossil CO_2 to the atmosphere, whereas CDR, in principle, lead to a net reduction in atmospheric CO_2. Second, because each engineered solution encompasses its own set of technologies at varying stages of development, with different market needs, limitations and concerns. And third, because biomass-based technologies involve significantly longer, often international, and typically complex supply chains, raising difficult and bespoke questions for full life-cycle carbon accounting (Fajardy and Mac Dowelll, 2018; Hayat et al., 2024).

Notwithstanding, both Mit-CCS and CDR refer to technologies which are part of supply chains for the transport and storage of captured CO_2 in underground formations over geological time-periods. In the case of the UK, these are made up mostly of saline aquifers and depleted offshore oil and gas fields in the North Sea. The existence of an operational transport and storage infrastructure is therefore a pre-requisite for both CDR and Mit-CCS options. While this could utilise existing natural gas pipeline infrastructure (Mahmoud and Dodds, 2022), it is expected that a large CO_2 pipeline network will need to be built to deliver the levels of storage required. In the short-to-medium term, it is likely that non-pipeline transport (e.g. freight, haulage, intermediary storage) will be needed to support more flexible transport and storage solutions and increase accessibility to CCS networks for firms at dispersed sites outside of industrial clusters.

For the sake of brevity, and clarity of focus, this report limits itself to engineered removals with a view to the permanent storage of captured CO_2. We note however that other concepts may be equally as important for our future energy pathways, and that CDR include wider families of approaches than discussed in this report. Nature-based solutions, like afforestation or soil and ecosystem restoration, rely on natural processes to capture and store CO_2 and are expected to sequester 44 $MtCO_2$/yr by 2050 under the CCC's CB7 assessment (Climate Change Committee, 2025a). Carbon capture and utilisation (CCU) describes supply chains that deploy captured carbon to offset fossil use or provide durable storage in physical infrastructure and materials – e.g. the production of platform chemicals, the carbonation of concrete, or the use of wood in construction.

1.2. Why we are likely to need CCS

Recent analysis shows that we are expected to regularly overshoot the Paris Agreement's temperature target of 1.5°C of global warming in around five years' time (Forster et al., 2025). Even drastic and immediate emission cuts are unlikely to avert temperature overshoot later in the century, increasing the risk of triggering irreversible tipping points, thus setting off cascading and potentially irreversible climate impacts (IPCC, 2022b). In this context, CDR-CCS can provide "net negative CO_2 emissions", reducing radiative forcing and thus scaling global average temperatures back below overshoot levels, minimising the time that we spend exceeding dangerous thresholds.

In this context, whilst the UK has made significant efforts to lower its contribution to global emissions, cutting its territorial emissions by almost half since 1990 (Climate Change Committee, 2025b), progress beyond displacing coal in the power supply and increasing supply side technology efficiency remains slow or has stagnated. A lack of consistent policy action to rollout low-carbon end use technologies or support social change has locked in emissions in the buildings and transport sectors. Furthermore, specific sectors and economic activities remain "hard-to-decarbonise" as alternative abatement methods do not exist, such as agricultural emissions, long haul aviation and shipping, as well as some emissions-intensive industrial activities. This will then require both Mit-CCS, a mitigation option that can be integrated into the energy system without wholesale changes (Bui et al., 2018), and compensatory CDR-CCS, to balance carbon budgets and ensure the whole system meets its net zero targets.

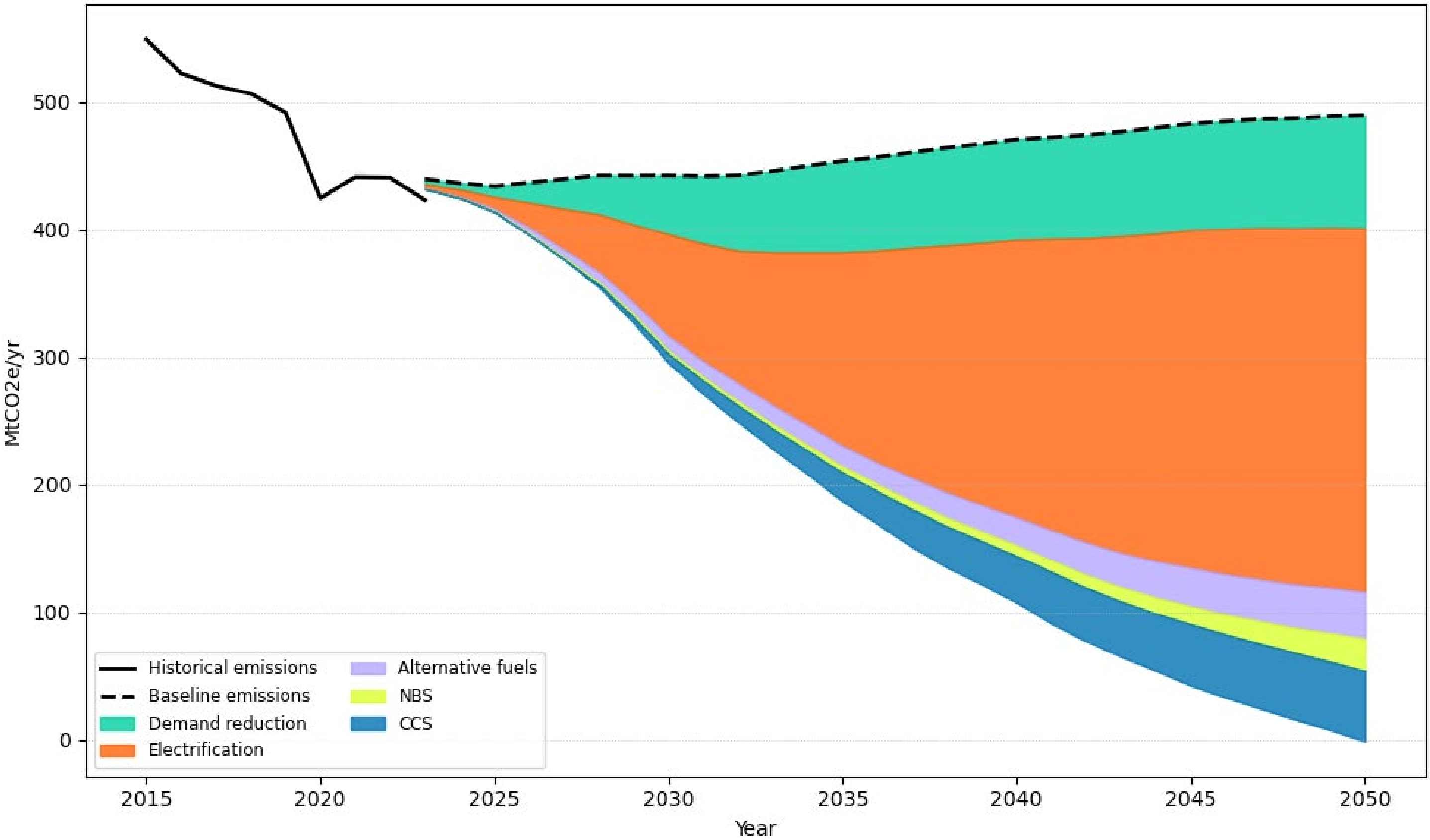
Going further, current mechanisms for reporting emissions use territorial-based accounting, and do not account for historic responsibility. When measured from a consumption-based perspective, the UK's emissions embodied in imports continue to rise (Defra, 2025), reflecting how domestic consumption continues to contribute to global emissions outside of its direct, statutory responsibility. Similarly, considering historic emissions may shift perspectives, as the UK's contribution towards cumulative global emissions (and therefore global mean temperature change) far outweighs an equal per-capita share of emissions over time (Matthews, 2016). Taken together, these perspectives suggest the UK could be expected to go beyond current emissions targets, with a medium-to-long term goal of providing significant net-removals, which would require corresponding amounts of CDR-CCS.

In this context, the UK has potential to be a global leader in CCS and policy developments indicate the UK Government is pursuing ambitious CCS deployment with cross-party political support (DESNZ, 2023a; HM Government, 2025, 2021). The UK has a highly skilled workforce in the relevant sectors (e.g. oil and gas engineering), pre-existing infrastructure and a wealth of geological sites for storage. Further to this, the UK has long-funded funded a series of research projects on CCS and carbon dioxide removal (HM Government, 2023), including one greenhouse gas removal project from 2017-2021, as well as two more recent programmes that have a greater focus on demonstration (UCL, 2021). Despite this, scaling up the deployment of CCS technologies from a limited base remains a huge task.

1.3. The scale of the CCS challenge

Significant CCS capacity is expected to be deployed in the UK over the next 25 years. The CCC estimates that around 40 $MtCO_2$/yr of Mit-CCS and 33 $MtCO_2$/yr of CDR-CCS will be required to meet its Net Zero target in 2050, as shown in Figure 2. That's around a 1/10th contribution to Net Zero in 2050.

Figure 2: The contribution of emissions reductions measures towards the CCC's Seventh Carbon Budget Balanced Pathway. NBS = nature-based solutions (e.g. a/reforestation, peatland restoration etc.). Data: Climate Change Committee (2025a)



Planned CCS projects in the UK are shown below in Table 1, highlighting a 2030 deployment of 5-10 $MtCO_2$/yr. However, the CCC cites insufficient policy plans to meet 2030 and 2035 targets relating to CCS and CDR (Climate Change Committee, 2025b).

Table 1: CCS projects in development as part of the UK Government's cluster sequencing strategy

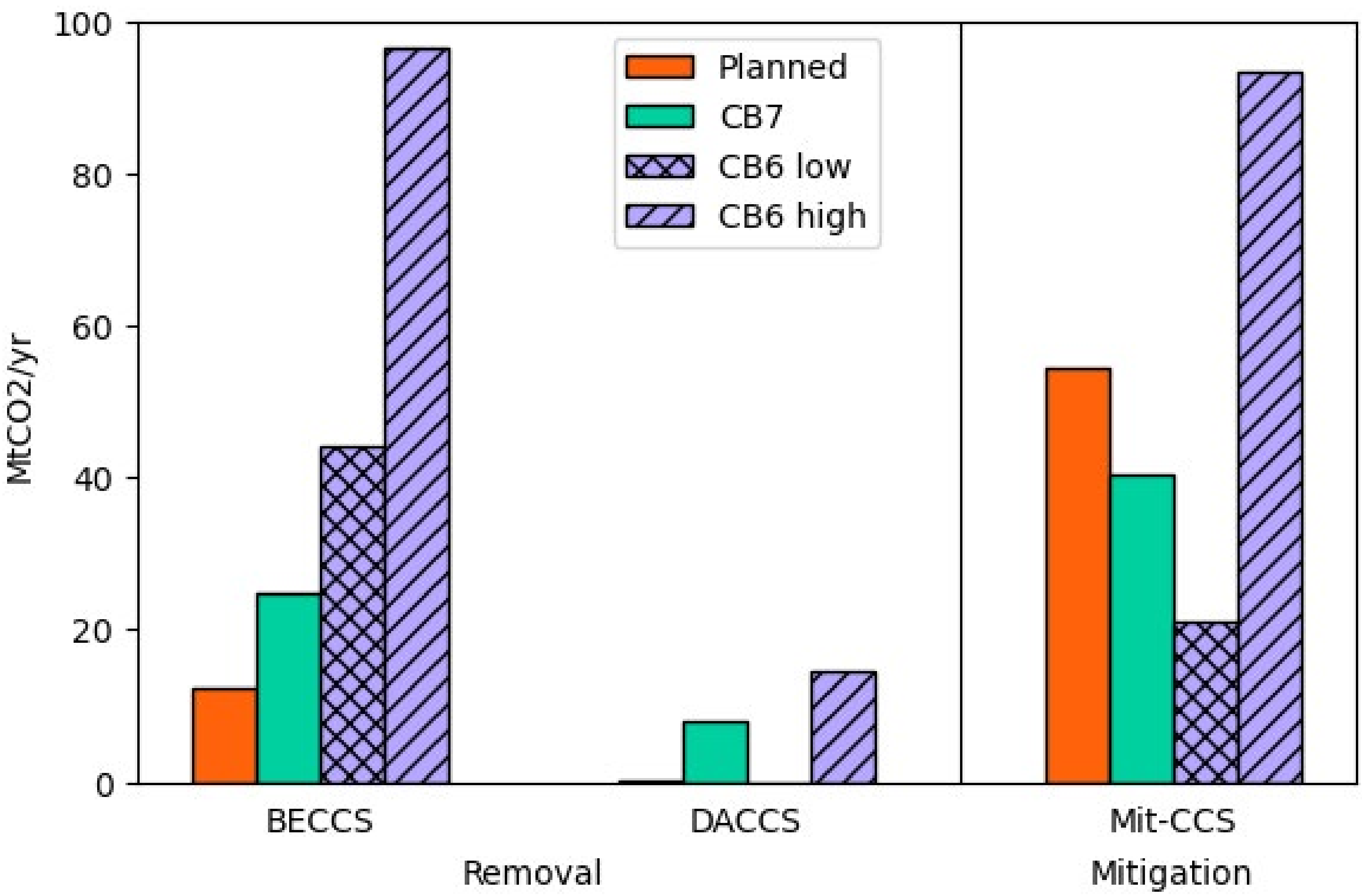
Track	Cluster	Project	Type	Expected capacity ($MtCO_2$/yr)	Expected deployment
Track 1	East Coast Cluster	Net Zero Teesside Power	CCGT power generation with CCS (Mit-CCS)	2	2028
		H2Teesside	Hydrogen production (Mit-CCS)	2*	2027 & 2030
		Teesside Hydrogen CO2 Capture	Hydrogen production (Mit-CCS)	No data	No data
	HyNet Cluster	Hanson Padeswood Cement Works	Cement production (Mit-CCS)	0.8	2028
		Viridor Runcorn Industrial CCS	Energy from Waste (Mit & CDR-CCS)	0.9	2025
		Protos Energy Recovery Facility	Energy from Waste (Mit & CDR-CCS)	No data	No data
		Buxton Lime Net Zero	Cement production (Mit-CCS)	0.02	
		HPP1	Hydrogen production (Mit-CCS)	0.65	2027
Track 2	Acorn Cluster	Track 2 clusters have been named as best placed to deliver according to the identified criteria, but no specific projects have been identified to date.			
	Viking Cluster				

* = Half the capacity is expected to be delivered by 2027, with the other half delivered by 2030.

To date, no CCS projects have been built in the UK, and as would be expected with any emerging suite of technologies, numerous challenges remain in upscaling these large infrastructure projects.

As shown in Figure 3, planned capacity (defined as the amount of emissions captured and stored per year) by 2050 remains far behind what could be required. We calculate the gap between current CCS plans for the UK and estimated capacity from the CCC's 6th and 7th Carbon Budgets (CB6 and CB7) analyses (Climate Change Committee, 2025a, 2020). Plans are assessed for each technology type (Mit-CCS and CDR, broken down by BECCS and DACCS). Figure 3 illustrates that current plans for capacity build out to 2035 remain significantly lower than is required by 2050. Whilst this is expected given the timescales we are assessing, we show the scale of the rollout necessary from the current operating space.

Figure 3: Total CCS demand (planned projects vs CCC estimates) in 2050, broken down by technology type.



2. Current challenges to CCS technology deployment

Mit-CCS and CDR technologies are part of complex chains of technologies that are not widely demonstrated at scale.

While some links in this chain are well-established with years of practical experience, examples of complete supply chains at scale remain limited. Carbon capture facilities have existed for nearly 30 years (Furre et al., 2017), and technology readiness for multiple components of the CCS supply chain is high (Kearns et al., 2021), yet global examples of full Mit-CCS or CDR-CCS supply chains remain limited. Operational carbon capture capacity globally stands at an estimated 50.9 Mt CO_2 per year, with a further 21.4 Mt under construction (IEA, 2025). The majority (80.5%) of these projects are fossil mitigation. For context, current UK net territorial emissions represent 371 $MtCO_2e$ (DESNZ, 2025). As of 2024, BECCS and DACCS contributed 0.51 and 0.004 $MtCO_2$ of global removals per year. Combined, this represents 0.06% of the carbon dioxide removals that currently come from natural systems[1] (Smith et al., 2024).

Capturing, transporting and storing atmospheric CO2 has been part of international policy discussions for decades (United Nations, 1998), and the UK has been a strong advocate for climate policy in similar spheres for just as long (Moulton, 2020). Yet, two competitions for funding to support the demonstration of CCS at scale were developed over several years between 2007-11 and 2012-15, but dropped without selecting a champion, costing a total of £168m and eroding investor confidence (NAO, 2017).

More recently, the UK is taking a clustered “track” approach to industrial decarbonisation, focussing efforts on several regions with high levels of industrial activity and emissions (HM Government, 2021). This approach aims to drive down costs and act as a catalyst for the widespread deployment of CCUS by fostering shared learning and infrastructures (Rattle and Taylor, 2023). Track 1 focusses on the early deployment of carbon capture projects in the HyNet and East Coast clusters by the mid-2020s. Track 2 aims to build upon the first phase, developing two further CCS clusters in Scotland (Acorn CCS) and the Humber (Viking CCS) (DESNZ, 2023b).

[1] 2.2Gt CO_2 removals per year from afforestation, reforestation, and managed forests.

Domestic policy to demonstrate political support, provide long-term funding, and the necessary regulatory frameworks to support these technologies has repeatedly faltered.

(Hudson, 2024).

The current Labour government has confirmed funding support promised by their predecessor, pledging £21.7bn over 25 years to support CCS development in industrial clusters in Teesside and Merseyside (HM Government, 2025). While the level of strategic detail and the scale of funding far exceeds previous attempts to develop a CCS market in the UK, competing signals from government remain. As previously stated targets of storing 20-30 $MtCO_2$/yr by 2030 have been dropped (Committee of Public Accounts, 2025). Since the development of this approach to industrial decarbonisation, research has shown how political and populist movements have built on societal emotions in relation to the transitions that lie ahead, showing the leveraging of disinformation leading to fraught, obscured, and increasingly polarised debates around – even – the need for climate and net zero policies (Hochachka et al., 2025; Piatek et al., 2024).

As a result, we now have a significant window of opportunity in funding terms, material progress in key areas of the country, but as yet no operational CCS plant in the UK, with potential for political pushback on the horizon.

CCS technology chains are "lumpy" and, as such, can only feasibly be delivered "at scale". Mit-CCS and CDR supply chains are complex. They involve large and capital-intensive infrastructure, often with indivisible components. They bring together a wide range of stakeholders faced with different incentives and different challenges. And they are likely to cross international borders, thus operating across different geographies and institutional governance frameworks. A review of CCS projects since 1995 suggests that support mechanisms typically fail to balance significant and inherent risks of upscaling such complex projects with the potential for viable returns across the multiple investors involved[2]. It further highlights the diversity of risks involved, from cancellation or delay of any link in the chain through to lack of public acceptance, and points to them being compounded by negative feedback where past failures lead to increased perceptions of risk (Wang et al., 2021).

This aligns with literature showing the difficulty of scaling lumpy technologies, including CCS, and highlighting the difference in performance (more jobs created, faster deployment, more distributed benefits) typically seen from investment portfolios and stimulus programmes that target more granular energy technologies (Wilson et al., 2023). Yet the estimated rates of scaling required for CCS by the 2040s (globally) are significant. Deployment will need to accelerate as fast as, or faster than, past known examples of granular (wind power) and lumpy (nuclear) technologies alike (Kazlou et al., 2024). Recent programmes are focused on early stages of demonstration and R&D, with long timeframes for scale-up and deployment typical (Nemet et al., 2018). As of 2024, indicators of innovation show that activity is generally intensifying (Smith et al., 2024), but there is still a long way to go to reach deployment at scale.

[2] Characterised as an inability of projects to derive economic output in the absence of a high carbon prices.

In this context, the slow and faltering delivery in CCS deployment has raised concerns of mitigation deterrence.

(McLaren, 2020)

Or, the delay of mitigation actions with the expectation of future CCS technology availability. This can take many forms. It includes the continued use of, and investment in, unabated fossil fuels as Mit-CCS retrofits or CDR-CCS are developed; the displacement of cheap variable renewables for power by BECCS technologies, which can provide two useful outputs; or the extrapolation of arguments that continued use of fossil fuel will be required in 2050, and beyond, to justify both domestic and global investment in new fossil extraction over clean energy and system change – examples of which have already played out on the international stage (McLaren et al., 2019). More generally, it highlights the deep sensitivity of near-term low-carbon pathways to assumptions about CDR availability, and risks building future systems which could breach global temperature goals by 0.2-0.3°C or require up to 17 GtCO_2 additional emissions reduction even under small changes of CDR deployment, such as a 20% chance of CDR deployment failure (Grant et al., 2021). Some high emitters in the UK industry are pursuing decarbonisation options without waiting for the availability of CCS (e.g. Port Talbot is adopting electric arc furnaces for steel production). However, failure to deploy CCS could risk decarbonisation pathways in key industrial clusters and in other sectors more widely – either directly, by pushing back decarbonisation timelines, or indirectly, as sunken CCS investments costs may limit the fiscal capacity of firms to choose an alternative emissions reduction pathway in the future.

With some exceptions, such as Korea, Norway and Canada, most countries' quantified NDC commitments are constituted by a singular "net" emissions reduction (Lamb et al., 2024), which obfuscates the relative contributions of emissions reductions and removals in emissions pathways. Such an approach has led to myopic climate policy, potentially encouraging and locking-in fossil-fuel intensive socio-technical configurations by de-emphasising the role of near-term absolute emissions reductions and over-emphasising the role of carbon removals in offset regimes (Brad and Schneider, 2025; McLaren et al., 2019). As such, many have advocated for the separation of these targets (Betts-Davies et al., 2024), highlighting the importance of pursuing near-term emissions reductions, promoting the use of negative emissions technologies exclusively to balance out emissions from sectors that are hard to decarbonise and giving clear indications to policymakers and markets regarding the timescales of deployment required for negative emissions technologies.

3. Assessing the feasibility of UK CCS deployment plans to 2050

It appears increasingly clear that CCS technologies will play a crucial role in the future UK energy system.

While the scale and scope of this role is yet uncertain, understanding how current plans compare to authoritative estimates of future needs is important. We consider future planned CCS capacity at the aggregate level as listed by the IEA (IEA, 2025), which is a worldwide dataset that covers all large-scale CO_2 capture, transport, storage and utilisation project at all stages of development (from planning to commissioning). Any projects that did not have an estimated capacity (of CO_2 capture or storage) were excluded. None of the UK projects with an estimated capacity were intended for CO_2 utilisation (CCU), so every project is intended for carbon capture with dedicated storage. The dataset lists the sector the project operates in (e.g. power and heat, chemicals, DAC etc.) as well as links to accompanying documentation and press releases, which give project details. Reviewing current plans across these categories highlights the scale of the role that CCS could be expected to play in the UK. Placing plans alongside future pathways contextualises each approach and their possible implications (e.g. in terms of varying resource requirements for each option). To address the question of the feasibility of planned build out rates, we take two estimation approaches, covered next.

3.1. Method 1 - Failure rate assessment

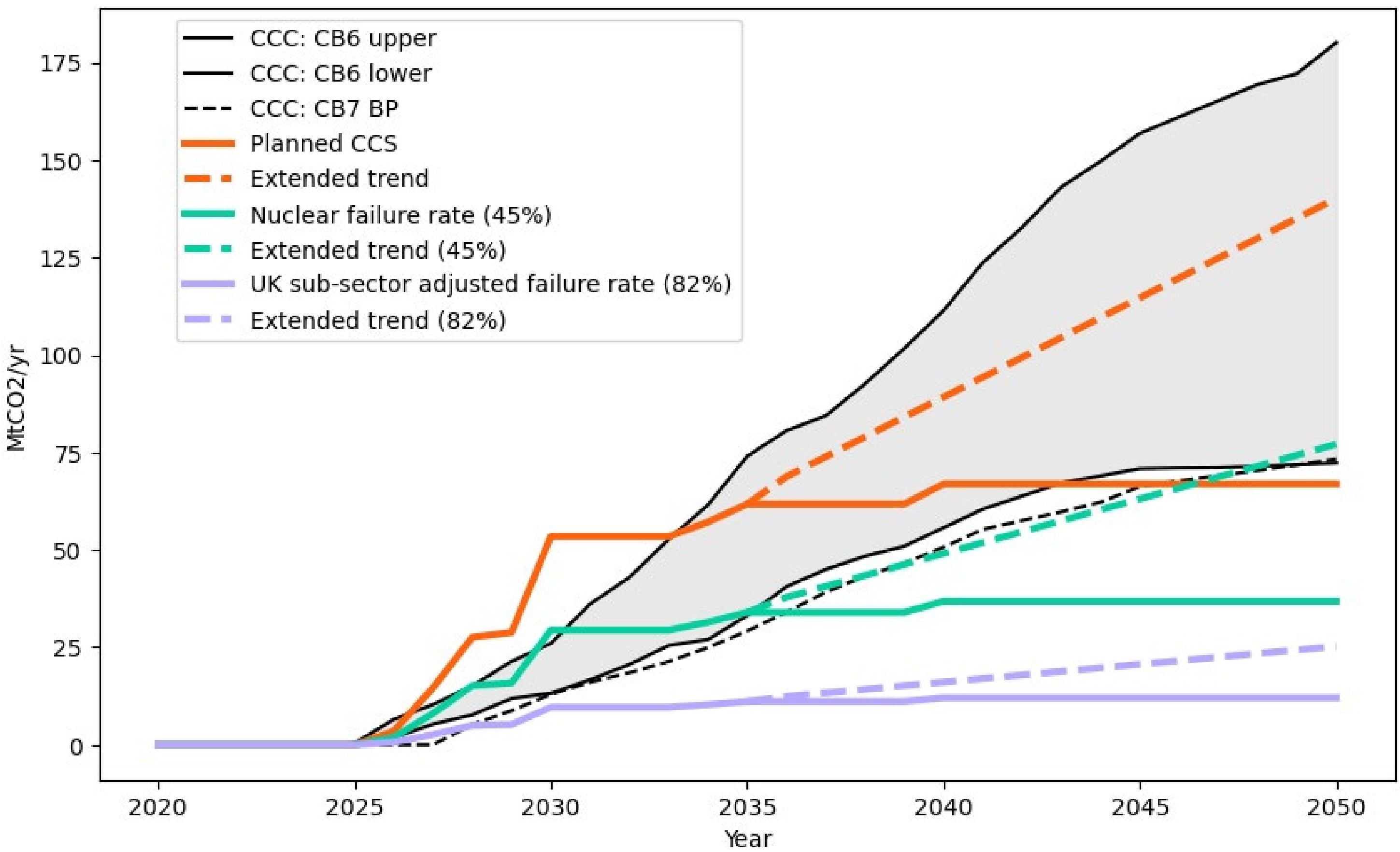
First, we compare planned CCS capacity from the IEA database with authoritative expectations of required CCS deployment by 2050 on an aggregate basis, to highlight where the CCS gap might lie, and show how significant it might be. This is incomplete as it does not account for projects that will likely be proposed in the coming years, or for potential failure of current and future CCS capacity to reach the market. To account for this, we linearly extrapolate plans from 2025-2035 out to 2050 to see whether they meet the required estimates from CB6 and CB7.

We also adopt the concept of failure rates (FRs), which are taken from (Kazlou et al., 2024). These FRs represent the proportion of planned capacity that could be expected to not become operational They range from 82% (historical global CCS failure rate) to 45% (the failure rate of early nuclear power projects in the US), to 0% (assuming that all planned projects become operational). Using these failure rates allows for an assessment of feasible CCS deployment scenarios, based on the assumption that some planned capacity will fail to materialise. Note that we take global CCS failure data and use a weighted average based on technologies being proposed in the UK, thus avoiding distortion by any others not currently expected to be part of the UK's energy system.

The 45% failure rate represents the proportion of US nuclear power plant capacity that was cancelled during its early development from 1972-1982. This is an appropriate refence case for three reasons. First, during this period, nuclear power generation was only being developed by a few pioneering countries (the same could be said about the UK and CCS development now). Second, the global share of nuclear power generation was very low (~2.5%), and was thus in its formative phase of development (Kazlou et al., 2024). Third, nuclear power shares many similarities with CCS technologies, due to its complexity, lumpiness and capital intensity. The 45% rate, calculated by Kazlou et al., defines project cancellations according to whether the project had placed an order (and subsequently terminated the contract) for a nuclear steam supply system, and thus had dedicated a significant sum of capital investment towards the project – as opposed to simply announcing intention to build capacity, or applying for a construction permit (Energy Information Administration, 1983).

This approach offers one way, among others, of considering future CCS deployment trajectories in the UK, describing whether, and under what conditions, they can meet the needs we are likely to have. The range of CCS futures described through this approach are shown in Figure 4.

Figure 4: Planned CO2 capture in the UK (coloured lines) and CCC estimates of future requirements (black lines).



Different colours show different expected failure rates for planned CCS (orange = no failure; green = 45%; purple = 82%). Dotted colours show linear extrapolation of future CCS plans between 2035 and 2050. Grey shading highlights the range of CCS estimates contained in CCC CB6.

First, it appears that half of the scenarios described above could meet the UK's combined 2050 CCS needs as suggested by the CCC CB6 & 7. Considering the full and dashed orange, the lines show current and extrapolated CCS plans exceeding expected needs up until 2035, before then falling within the CCC carbon budget range for 2050 at the aggregate level. Looking at the dashed green line shows that this outcome holds with a 45% FR, if the ambition seen in plans for 2025-35 does not weaken before the end of the period.

Second, however, it appears that combining current trajectories with the existing track record of CCS project delivery would make reaching national capacity requirements unlikely, both in 2035 and in 2050 (see purple lines). Historical failure rates in the CCS sector are close to double those seen in the US nuclear programme. As a result, even sustaining the 2025-35 expansion ambition (dashed purple) may deliver as little as 25 $MtCO_2$/yr by 2050, just 34% of the amount suggested by the CCC CB7.

Importantly, these results highlight the level of effort still required to transition from the early stages of CCS technology growth through to the development of an established industry. It is expected that "learning by doing" will, and indeed has already started to, bridge this gap. Studying Sweden, Beiron and Johnsson (2024) show that high learning rates seen for "similar" technologies[3] can lead to N^{th}-of-a-kind CCS[4] costs within 30 projects. But they also consider that conservative learning might, for the same cumulative capacity, only cut costs by 10-20%. It is currently unclear what learning rates to expect, and CCS technologies include very diverse options. It has for example been highlighted that achieving higher learnings for Mit-CCS retrofit options may be ambitious because high degrees of customisation and site specificity are expected (Kumar, 2024; Malhotra and Schmidt, 2020).

While data overall is still sparse, we show here that, across all CCS options, failure rates must be halved in the very near-term if we are to deliver against CCC CB7 pathway needs by 2050. This will not happen without clear and sustained policy support over a considerable time period that go beyond typical political cycles (Lipponen et al., 2017).

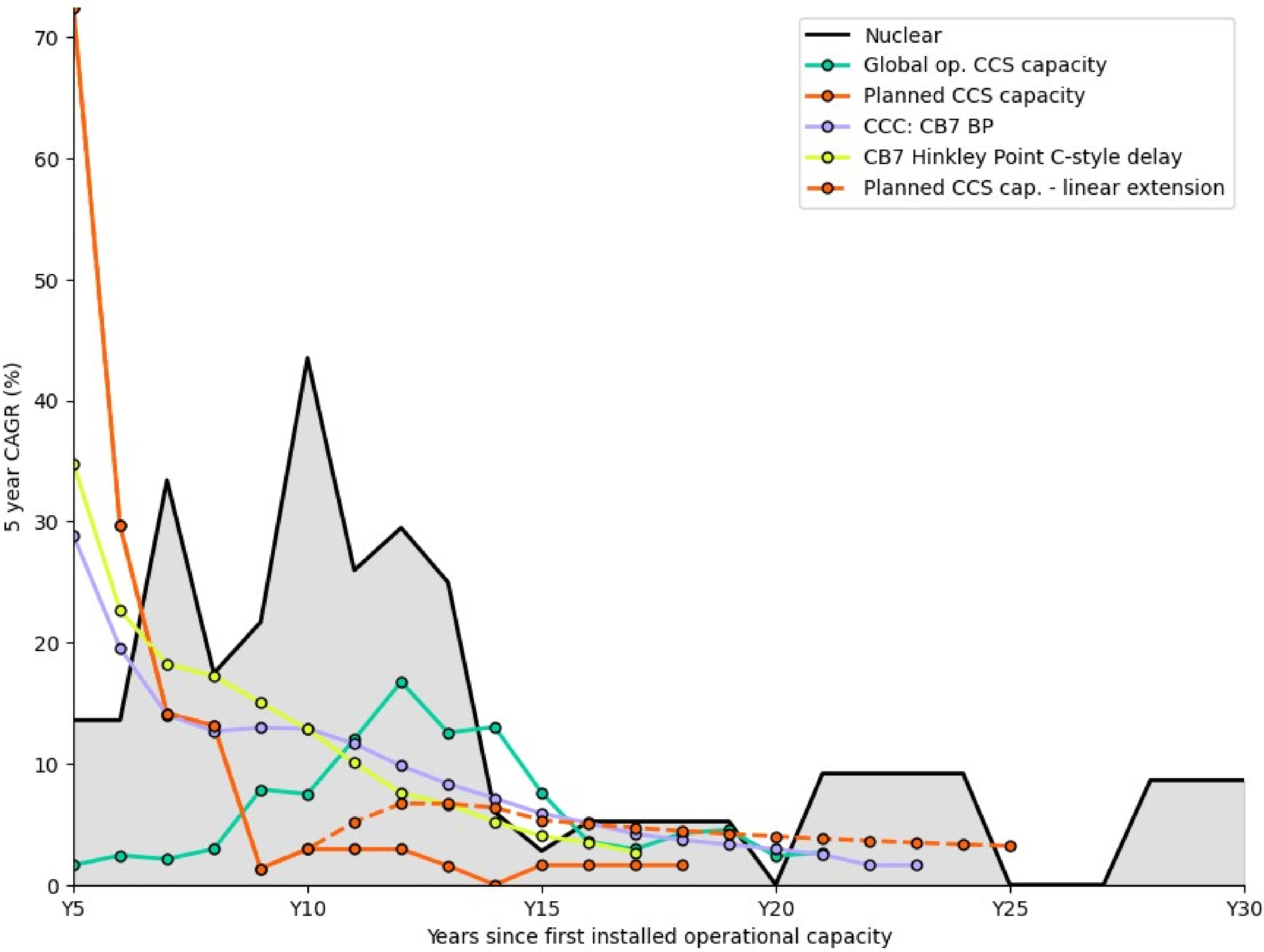
[3] Learning rates understood here as the % by which the project cost is reduced each time the total installed capacity doubles. Beiron et al. refer to 12%-14% values seen for wet scrubber flue gas cleaning technology between 1970-2000.

[4] Defined there as carbon capture retrofit to industrial heat and power emission sources.

3.2. Method 2 - Assessing CAGRs

Next, we assess the compound annual growth rates (CAGRs) of CCS as an emerging technology, and the build-up rates in CAGR terms. We adopt technological analogues by comparing planned CCS deployment rates to historical nuclear power capacity deployment rates in the UK, as this is a similarly lumpy and capital-intensive technology. This allows us to explore whether assumed deployment rates fit within a reasonable feasibility range, which represents the realistic limits of technology deployment growth, implied by the historical performance of analogous large-scale energy technologies. Given the history of CCS delays and cancellations in the UK, we also explore the capacity growth rates of CB7 CCS deployment under the scenario of a Hinkley Point C-style delay. Under this scenario, CCS capacity still reaches the required levels as set out in the CB7 Balanced Pathway scenario, but initial deployment is delayed by 6 years.

Figure 5: Comparison of 5-year compound annual growth rate (CAGR) of CCS deployment and technologies already deployed in the UK.



Existing low carbon technologies (UK operational capacity, black lines), global operational capacity of CCS (green line), planned CCS capacity in the UK (orange line) and a linear extension of the trend (dashed orange), CCS capacity in the CB7 scenario (purple line) and the same CB7 data but with a 6-year delay before the first capacity installations are deployed (yellow line) The x-axis shows the years since each respective technology was first installed.

Figure 5 shows that nuclear power sees an early surge lasting around 10 years and reaches maximum 5-year CAGR peaks of 33 and 43% in Y7 and Y10, respectively, after first deployment. Besides these peaks, nuclear CAGRs range from 0-29%, with the average value of nuclear power's CAGR from Y5-Y30 sitting at 12%/yr. The 5-year CAGRs for current CCS plans are very high in the near term and meeting targets for 2030 will mean values of 75% for the first 5-year period. Levels then drop to significantly lower values, falling to 13% in Y8 and fluctuating between 0-3% from Y9 onwards, reflecting fewer projects being planned beyond 2035. If we considered the extended trend that we applied earlier from Figure 4, five-year CAGR values would instead sit between 3-7% between Y12-25.

Contrasting planned projects with expected needs as presented under CB7 (orange vs. purple lines in Figure 4) highlights that the CCC describes a slower deployment of CCS technologies than is proposed by industry. This would allow initial 5-year CAGRs to drop by 60% but assumes higher sustained growth over longer periods of time thereafter.

Finally, considering a Hinkley-C type delay (yellow vs. purple lines in Figure 4) while assuming we still deliver similar levels of CCS by 2050 compresses new capacity buildout into a tighter timeframe. This increases 5-year CAGRs: Y5 values increase to 34.8% and average values to 2050 increase by almost 50%. While these arguably remain within the range of past nuclear power values, the shift is significant as it highlights the delivery challenge of having fixed emissions targets for 2050 that will rely on given levels of CCS.

Overall, values for CCS show a trajectory that quickly seems reasonable when compared to historical rates of nuclear power generation deployment. However, deployment rates are high in the early years of deployment, for both planned CCS deployment and CCC estimates, which is a key timeframe for market development and investor confidence.

3.3. Implications for CCS deployment in the UK

Current planned CCS deployment represents a significant shift from demonstration projects to large scale commercial carbon capture, transportation and storage. While comparable nuclear technologies suggest similar roll-out patterns have been achieved, it is important to note that these options were connected to existing grid infrastructure and inserted into an existing system. Conversely, CCS options need to be built at the same time as the supply chains they are part of. More gradual CCS integration, as suggest under CCC trajectories, may reduce the risks associated with failure (Wang et al., 2021), but will still expect CCS capacity to grow from zero to 29 $MtCO_2$/yr over by 2035. Early technology roll-out needs to be fast and show significant growth, displaying better performance than global operational CCS capacity to date (green line in Figure 5). Any delays compound the challenge, and have, in the past led to investors pulling out of planned CCS projects (Hudson, 2024), with the collapse of complex global supply chains that are still in their infancy being a very real possibility. In real UK terms, delays to current Government Track 1 projects in the next 5 years risks undermining investor confidence and could result in the UK missing proposed carbon budgets and carbon capture targets.

It stands to reason that significant policy and investment support will be required for CCS technologies and their supply chains to grow at the rates required to achieve decarbonisation targets. The UK Government is in the process of developing an innovative policy framework, aimed at reducing risks for investors (via subsidies, capital grant funding and revenue protection via CCS Contracts for Difference) to produce first-of-a-kind deployment and generate viable CCS markets. This includes bespoke business models for each part of the CCS value chain, to manage subsector-specific barriers, with a key focus on mitigating cross-chain risk (e.g. misalignment between carbon capture plants and transport-and-storage development timelines – as shown in Appendix B) (*CCUS Business Models and Building Viable CCUS Projects*, 2023).

Ultimately, any delays to transport and storage infrastructure developments will have knock on effects on carbon removal markets and the ability for Mit-CCS and removals to contribute towards UK decarbonisation. As things stand, carbon capture and removal targets are currently not on target to be met (Lomax et al., 2025).

Whilst our analysis offers an aggregated view of CCS projects and capacity, neglecting the differentiated risks and opportunities of the various CCS technologies, it highlights the risks associated with the massive deployment of a suite of technologies that, to date, have not been proven at scale. However, the data displayed in Figure 3 shows the comparison of current plans with possible future needs for 2050 for mitigation and removal CCS options. Mitigation options represent the majority (86%) of current plans with a total of 54 $MtCO_2$/yr of capture capacity. The latest needs assessment published in CB7 suggest that, as part of wider system changes, 40.5 $MtCO_2$/yr could be sufficient, thus allowing for up to 31% of current plans (in capacity terms) to fail. This is still significantly lower than the FR for early US nuclear projects described above.

Planned CDR capacity is low both in absolute terms, and when compared to expected requirements for meeting net zero by 2050. Plans for BECCS and DACS projects currently stand at 12 and 0.05 $MtCO_2$/yr respectively, with expected needs under CB6-7 varying between 44-97 and 0-14 $MtCO_2$/yr. For BECCS, this implies a threefold scaleup from existing plans to 2050, without allowing for failures to materialise.

For DACCS, it highlights that significant challenges remain in establishing initial projects that could be considered "at scale". This is all the more challenging when contrasted with previous government objectives of reaching removals of 5 $MtCO_2$/yr through direct air capture by 2030, with a view to scale up to 23 $MtCO_2$/yr just five years later (BEIS, 2021; DESNZ, 2023c).

Furthermore, the over-reliance on Mit-CCS in deployment plans so far points to a risk of mitigation deterrence. Such an approach, which prioritises a lower risk approach than diverting resources towards removals, maintains existing (or develops brand new) fossil fuel infrastructure potentially locking-in carbon intensive systems. This can reduce the urgency of transformative systemic change (e.g. renewable deployment, electrification and demand reduction) by assuming CCS can compensate later.

Overall, there are risks involved with all possible pathways to reaching our net zero goals and therefore understanding what each route could imply is key. Yet considering future expectations for CCS in the UK shows that a significant gap from current plans remains. It also highlights that the implied scale up is ambitious when considering project failure rates seen in other energy transitions. Because of the interconnected nature of the energy system, and the strict quality of a net-zero target, this raises valid questions as to our ability to deliver these CCS technologies in time and as to any contingency that might be considered for missing carbon capture or removals.

3.4. Limitations

This study has two main limitations. First, it does not consider the geographical dimensions of CCS development. We assume that failure rates are proportional to the share of CCS capacity lost. However, storage capacity, and future CCS needs, are not evenly distributed geographically or systematically co-located. The failure of early projects in key industrial clusters, either on the capture or T&S side early in the timeline of CCS deployment could have a disproportionately large knock-on effect on the development of a sustainable CCS market. Comparatively, the failure of smaller projects could be less significant. In principle, the cluster approach is intended to reduce these risks by sharing the costs of large, capital-intensive CCS projects across multiple firms and the public sector, and by designating key development locations.

Second, we assume a linear extrapolation of planned projects from 2035-2050, as opposed to a typical S-shaped curve adoption assumption. Adopting an S-shaped curve could lead to a steeper increase in more capacity by 2050 – implying that failure rates do not need to improve as much. However, this would also imply higher 5-year CAGRs, which may not be feasible. We choose a linear approach to: (1) align with CCC assumptions which reflect a relatively linear adoption trend in their Balanced Pathway; (2) describe a range of realistic and plausible outcomes for CCS deployment, rather than a prediction of actual outcomes; and (3) S-curves have been criticised for not reflecting actual technology deployment trends.

4. Policy recommendations and conclusion

The development and deployment of CCS technologies represents a major challenge for decarbonisation in the UK.

Substantial amounts of CO_2 are estimated to be captured and stored underground by 2050 by a suite of technologies that do not currently have an established business model or market. To achieve the assumed rates of removals and mitigation CCS needs to be scaled up massively and failure rates must be reduced, but not at the expense of rapid, near-term emissions reductions.

For CCS projects to be deployed at the scale and speed necessary over the next 25 years, a favourable policy framework is beginning to be developed. Work to commercialise and scale CCS is underway but technology costs need to fall, and business models and supply chains need to be developed.

The policy window has re-opened, and UK Government interest is renewed by the net zero target and a cluster approach to industrial decarbonisation. However, risks remain for the widespread deployment of CCS technologies.

We suggest several policy recommendations designed to mitigate this risk.

First, political and financial support for CCS projects must be sustained over the long term. As successful pilot projects are developed this will create a positive feedback loop for investors that will reduce failure rates, but initial revenues need to be underwritten to create a viable market. It is welcomed that the UK Government has set out a plan to establish a self-sustaining CCS market (DESNZ, 2023a) and significant sums of money have been earmarked for CCS over the long term. However, lessons need to be learnt from previous experience, where money was ostensibly ringfenced for CCS projects but then reappropriated, leading to the collapse of commercial CCS projects (Hudson, 2024).

Second, strategies that reduce our total reliance on CCS will make the scale of deployment easier to achieve.

Limiting Mit-CCS to industrial sectors where there are no other cost-effective mitigation alternatives, such as cement production, rather than natural gas power stations, is one way of limiting the need for CCS to more feasible levels. Furthermore, reducing our demand for engineered removals and limiting it to compensate for hard-to-abate sectors and reversing temperature overshoot can reduce long-term system costs (Shindell and Rogelj, 2025). Pursuing stringent, near-term emissions reductions via demand reduction and the decarbonisation of energy supply limits cumulative emissions, reducing carbon removal requirements towards the second half of the century. Furthermore, the promise of CCS should not be used to justify expansions in fossil fuel capacity on the premise retrofit technology, which is not currently commercially available, will be a realistic option for dealing with emissions in the future. Incumbent players, including fossil fuel producers, may exploit the promise of CCS, and CDR in particular, to limit or delay climate action in the near term by overplaying the amount of carbon dioxide that can be sequestered in the future (Lamb et al., 2024).

Third, CCS strategy – and industrial decarbonisation more generally – needs to be flexible. The requirements of UK industry will change over shorter timeframes than the deployment of CCS technologies and other decarbonisation options alike (Rattle and Taylor, 2023). The potential failure of CCS projects, and the failure to deliver a functioning market, could drastically change these requirements. Ensuring that firms or clusters can adopt alternative mitigation measures (e.g. electrification) as economic or market circumstances change is not built into UK industrial decarbonisation strategy as it stands.

Fourth, the UK Government should consider innovative policy instruments, such as a Carbon Removal Obligation (Bednar et al., 2024) or Carbon Takeback Obligation (Jenkins et al., 2023; Kuijper et al., 2021), which ensure that those responsible for greenhouse gas emissions are liable for delivering the carbon removals required to reverse overshoot once a given carbon budget has been exhausted (i.e. the polluter pays principle is enforced). If designed properly, such obligations can reduce the risks associated with mitigation deterrence, ensuring that the promise of future atmospheric carbon removals do not undermine emissions reductions pathways in the near term.

Finally, public acceptance is key and can depend on a multitude of factors, such as trust in stakeholders, the perceived severity of climate change and risks associated with transport and storage (Große-Kreul et al., 2024) and, crucially, whether engineered removals can be developed and deployed fast enough to address the climate crisis (Cox et al., 2020). However, any future decarbonisation pathway will stress-test public acceptance. High levels of renewable deployment will require significant amounts of physical infrastructure across the nation’s landscapes to reinforce the power grid. Demand-led pathways call for considerable social, institutional and infrastructural changes. Similarly, CCS deployment will necessitate pipeline infrastructure, particularly around industrial clusters (it therefore has a spatial dimension that will affect different communities in different ways) and has implications for the continued use of fossil fuels. Public perceptions of risk and the potential for failures is therefore of the utmost importance and could determine the scale of deployment (Lai et al., 2025).

To conclude, momentum is building in the UK for CCS as an effective and viable option for decarbonising the economy. There is renewed policy interest and plans are maturing for CCS deployment across several industrial clusters. Two CCS projects have reached final investment decision stage and construction is expected to begin in 2026. However, there have been several false dawns before and there is a high degree of uncertainty regarding the potential for scaling up CCS markets so that the technologies can be deployed at scale. Furthermore, because of the risks of low or slow adoption, contingency mitigation measures need to be taken to insure against CCS projects and capacity failing to materialise at the scale estimated in modelling scenarios in the absence of viable CCS markets.

References

Bednar, J., Macinante, J., Baklanov, A., Hall, J.W., Wagner, F., Ghaleigh, N.S., Obersteiner, M., 2024. Beyond emissions trading to a negative carbon economy: a proposed carbon removal obligation and its implementation. Clim. Policy 24, 501–514. **https://doi.org/10.1080/14693062.2023.2276858**

Beiron, J., Johnsson, F., 2024. Progressing from first-of-a-kind to Nth-of-a-kind: Applying learning rates to carbon capture deployment in Sweden. Int. J. Greenh. Gas Control 137, 104226. **https://doi.org/10.1016/j.ijggc.2024.104226**

BEIS, 2021. Net Zero Strategy: Build Back Greener. HM Government, London, UK.

Bellona Europa, 2021. Models for Transport and Storage of Capture CO_2: A review of some options.

Betts-Davies, S., Barrett, J., Smith, C., Pye, S., Johnson, E., Price, J., 2024. Targets for effective climate mitigation governance in the UK. Priestley Centre Climate Evidence Unit. **https://doi.org/10.48785/100/281**

Brad, A., Schneider, E., 2025. Carbon removal, mitigation deterrence and the politics of target separation. Evidence from the EU 2040 climate target negotiation. Environ. Res. Lett. 20, 054074. **https://doi.org/10.1088/1748-9326/add0c9**

Bui, M., Adjiman, C.S., Bardow, A., Anthony, E.J., Boston, A., Brown, S., Fennell, P.S., Fuss, S., Galindo, A., Hackett, L.A., Hallett, J.P., Herzog, H.J., Jackson, G., Kemper, J., Krevor, S., Maitland, G.C., Matuszewski, M., Metcalfe, I.S., Petit, C., Puxty, G., Reimer, J., Reiner, D.M., Rubin, E.S., Scott, S.A., Shah, N., Smit, B., Trusler, J.P.M., Webley, P., Wilcox, J., Mac Dowell, N., 2018. Carbon capture and storage (CCS): the way forward. Energy Environ. Sci. 11, 1062–1176. **https://doi.org/10.1039/C7EE02342A**

CCUS Business Models and Building Viable CCUS Projects, 2023. , The Status of CCS in the UK - A Series.

Climate Change Committee, 2025a. The Seventh Carbon Budget.

Climate Change Committee, 2025b. Progress in reducing emissions – 2025 report to Parliament.

Climate Change Committee, 2020. The Sixth Carbon Budget: The UK's path to Net Zero.

Committee of Public Accounts, 2025. Carbon Capture, Usage and Storage [WWW Document]. GOV UK. URL **https://publications.parliament.uk/pa/cm5901/cmselect/cmpubacc/351/report.html (accessed 3.10.25).**

Cox, E., Spence, E., Pidgeon, N., 2020. Public perceptions of carbon dioxide removal in the United States and the United Kingdom. Nat. Clim. Change 10, 744–749. **https://doi.org/10.1038/s41558-020-0823-z**

Defra, 2025. Carbon footprint for the UK and England to 2022 [WWW Document]. GOV.UK. URL **https://www.gov.uk/government/statistics/uks-carbon-footprint/carbon-footprint-for-the-uk-and-england-to-2022** (accessed 6.16.25).

DESNZ, 2025. 2024 UK Greenhouse Gas Emissions, Provisional Figures. Department for Eneergy Security and Net Zero, London, UK.

DESNZ, 2023a. Carbon Capture, Usage and Storage: a vision to establish a competitive market. Department for Eneergy Security and Net Zero, London, UK.

DESNZ, 2023b. UK carbon capture, usage and storage (CCUS) [WWW Document]. GOV.UK. URL **https://www.gov.uk/government/collections/uk-carbon-capture-usage-and-storage-ccus** (accessed 8.4.25).

DESNZ, 2023c. Biomass Strategy. HM Government, London.

Energy Information Administration, 1983. Nuclear Plant Cancellatlons: Causes Costs, and Consequences. U.S. Department of Energy, Washington D.C.

Fajardy, M., Mac Dowelll, N., 2018. The energy return on investment of BECCS: is BECCS a threat to energy security? Environ. Sci. 11, 1581–2594.

Forster, P.M., Smith, C., Walsh, T., Lamb, W.F., Lamboll, R., Cassou, C., Hauser, M., Hausfather, Z., Lee, J.-Y., Palmer, M.D., von Schuckmann, K., Slangen, A.B.A., Szopa, S., Trewin, B., Yun, J., Gillett, N.P., Jenkins, S., Matthews, H.D., Raghavan, K., Ribes, A., Rogelj, J., Rosen, D., Zhang, X., Allen, M., Aleluia Reis, L., Andrew, R.M., Betts, R.A., Borger, A., Broersma, J.A., Burgess, S.N., Cheng, L., Friedlingstein, P., Domingues, C.M., Gambarini, M., Gasser, T., Gütschow, J., Ishii, M., Kadow, C., Kennedy, J., Killick, R.E., Krummel, P.B., Liné, A., Monselesan, D.P., Morice, C., Mühle, J., Naik, V., Peters, G.P., Pirani, A., Pongratz, J., Minx, J.C., Rigby, M., Rohde, R., Savita, A., Seneviratne, S.I., Thorne, P., Wells, C., Western, L.M., van der Werf, G.R., Wijffels, S.E., Masson-Delmotte, V., Zhai, P., 2025.

Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence. Earth Syst. Sci. Data 17, 2641–2680. **https://doi.org/10.5194/essd-17-2641-2025**

Furre, A.-K., Eiken, O., Alnes, H., Vevatne, J.N., Kiær, A.F., 2017. 20 Years of Monitoring CO_2-injection at Sleipner. Energy Procedia 114, 3916–3926. **https://doi.org/10.1016/j.egypro.2017.03.1523**

Grant, N., Hawkes, A., Mittal, S., Gambhir, A., 2021. Confronting mitigation deterrence in low-carbon scenarios. Environ. Res. Lett. 16, 064099. **https://doi.org/10.1088/1748-9326/ac0749**

Große-Kreul, F., Altstadt, L., Reichmann, A., Weber, N., Witte, K., 2024. Understanding public acceptance amidst controversy and ignorance: The case of industrial Carbon Capture and Storage in Germany. Energy Res. Soc. Sci. 118, 103838. **https://doi.org/10.1016/j.erss.2024.103838**

Hayat, M.A., Alhadhrami, K., Elshurafa, A.M., 2024. Which bioenergy with carbon capture and storage (BECCS) pathways can provide net-negative emissions? Int. J. Greenh. Gas Control 135, 104164. **https://doi.org/10.1016/j.ijggc.2024.104164**

HM Government, 2025. Major carbon capture project to deliver jobs and growth [WWW Document]. GOV.UK. URL **https://www.gov.uk/government/news/major-carbon-capture-project-to-deliver-jobs-and-growth (accessed 5.8.25).**

HM Government, 2023. CCUS Net Zero Investment Roadmap.

HM Government, 2021. Industrial decarbonisation strategy. Home Office, London.

Hochachka, G., Wise, M., Regan, W., 2025. 'Sensemaking' climate change: navigating policy, polarization and the culture wars. Npj Clim. Action 4, 43. **https://doi.org/10.1038/s44168-025-00240-7**

Hudson, M., 2024. Carbon Capture and Storage in the UK: History, Policies and Politics, 1st ed. Routledge, London, UK.

IEA, 2025. CCUS Projects Explorer – Data Tools [WWW Document]. IEA. URL **https://www.iea.org/data-and-statistics/data-tools/ccus-projects-explorer (accessed 5.7.25**).

IPCC, 2022a. IPCC AR6 WGIII CDR Factsheet. UNEP.

IPCC, 2022b. Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty, 1st ed. Cambridge University Press. **https://doi.org/10.1017/9781009157940**

Jenkins, S., Kuijper, M., Helferty, H., Girardin, C., Allen, M., 2023. Extended producer responsibility for fossil fuels. Environ. Res. Lett. 18, 011005. **https://doi.org/10.1088/1748-9326/aca4e8**

Kazlou, T., Cherp, A., Jewell, J., 2024. Feasible deployment of carbon capture and storage and the requirements of climate targets. Nat. Clim. Change 14, 1047–1055. **https://doi.org/10.1038/s41558-024-02104-0**

Kearns, D., Liu, H., Consoli, C., 2021. Technological Readiness and Costs of CCS. Global CCS Institute.

Kuijper, M., Holleman, E., van Soest, J.P., 2021. Carbon Takeback Obligation A Producers Responsibility Scheme on the Way to a Climate Neutral Energy System.

Kumar, R., 2024. Decarbonization in Carbon-Intensive Industries - An Assessment Framework for Enhanced Early-Stage Identification of Optimal Decarbonization Pathways. Chalmers University of Technology.

Lai, H.-L., Devine-Wright, P., Hamilton, J., Mander, S., Clery, D., Rattle, I., Martin, A., Ryder, S., Taylor, P., 2025. A Place-based, Just Transition framework can guide industrial decarbonisation with a social licence. Energy Res. Soc. Sci. 121, 103967. **https://doi.org/10.1016/j.erss.2025.103967**

Lamb, William F., Gasser, T., Roman-Cuesta, R.M., Grassi, G., Gidden, M.J., Powis, C.M., Geden, O., Nemet, G., Pratama, Y., Riahi, K., Smith, S.M., Steinhauser, J., Vaughan, N.E., Smith, H.B., Minx, J.C., 2024. The carbon dioxide removal gap. Nat. Clim. Change 14, 644–651. **https://doi.org/10.1038/s41558-024-01984-6**

Lamb, William F, Schleussner, C.-F., Grassi, G., Smith, S.M., Gidden, M.J., Geden, O., Runge-Metzger, A., Vaughan, N.E., Nemet, G., Johnstone, I., Schulte, I., Minx, J.C., 2024. Countries need to provide clarity on the role of carbon dioxide removal in their climate pledges. Environ. Res. Lett. 19, 121001. **https://doi.org/10.1088/1748-9326/ad91c7**

Lipponen, J., McCulloch, S., Keeling, S., Stanley, T., Berghout, N., Berly, T., 2017. The Politics of Large-scale CCS Deployment. Energy Procedia 114, 7581–7595. **https://doi.org/10.1016/j.egypro.2017.03.1890**

Lomax, C., Smith, S.M., Bellamy, R., Wagle, A., 2025. The UK State of Carbon Dioxide Removal. Smith School of Enterprise and the Environment, University of Oxford, Oxford.

Mahmoud, R.M.A., Dodds, P.E., 2022. A technical evaluation to analyse of potential repurposing of submarine pipelines for hydrogen and CCS using survival analysis. Ocean Eng. 266, 112893. **https://doi.org/10.1016/j.oceaneng.2022.112893**

Malhotra, A., Schmidt, T.S., 2020. Accelerating Low-Carbon Innovation. Joule 4, 2259–2267. **https://doi.org/10.1016/j.joule.2020.09.004**

Matthews, H.D., 2016. Quantifying historical carbon and climate debts among nations. Nat. Clim. Change 6, 60–64. **https://doi.org/10.1038/nclimate2774**

McLaren, D., 2020. Quantifying the potential scale of mitigation deterrence from greenhouse gas removal techniques. Clim. Change 162, 2411–2428. **https://doi.org/10.1007/s10584-020-02732-3**

McLaren, D.P., Tyfield, D.P., Willis, R., Szerszynski, B., Markusson, N.O., 2019. Beyond "Net-Zero": A Case for Separate Targets for Emissions Reduction and Negative Emissions. Front. Clim. 1, 4. **https://doi.org/10.3389/fclim.2019.00004**

Middleton, R.S., Yaw, S., 2018.
The cost of getting CCS wrong: Uncertainty, infrastructure design, and stranded CO_2. Int. J. Greenh. Gas Control 70, 1–11.
https://doi.org/10.1016/j.ijggc.2017.12.011

Moulton, J., F.G., 2020.
Lessons from climate action in the UK: The limitations of state leadership, in: Climate Governance across the Globe: Pioneers, Leaders and Followers. Routledge, pp. 182–199.

NAO, 2017.
Carbon Capture and Storage the second competition for government support. House of Commons, London.

Nemet, G.F., Callaghan, M.W., Creutzig, F., Fuss, S., Hartmann, J., Hilaire, J., Lamb, W.F., Minx, J.C., Rogers, S., Smith, P., 2018. Negative emissions—Part 3: Innovation and upscaling. Environ. Res. Lett. 13, 063003.
https://doi.org/10.1088/1748-9326/aabff4

Piatek, S.J., Haines, A., Larson, H.J., 2024.
We need to tackle the growing threat of mis- and disinformation about climate change and health. BMJ q2187.
https://doi.org/10.1136/bmj.q2187

Rattle, I., Taylor, P.G.,
2023. Factors driving the decarbonisation of industrial clusters: A rapid evidence assessment of international experience. Energy Res. Soc. Sci. 105, 103265.
https://doi.org/10.1016/j.erss.2023.103265

Shindell, D., Rogelj, J., 2025.
Preserving carbon dioxide removal to serve critical needs. Nat. Clim. Change.
https://doi.org/10.1038/s41558-025-02251-y

Smith, S., Geden, O., Gidden, M., Lamb, W.F., Nemet, G.F., Minx, J., Buck, H., Burke, J., Cox, E., Edwards, M., Fuss, S., Johnstone, I., Müller-Hansen, F., Pongratz, J., Probst, B., Roe, S., Schenuit, F., Schulte, I., Vaughan, N., 2024.
The State of Carbon Dioxide Removal - 2nd Edition.
https://doi.org/10.17605/OSF.IO/F85QJ

UCL, 2021. Greenhouse gas removal programme wins £30million government funding | Bartlett Faculty of the Built Environment [WWW Document]. ucl.ac.uk. URL **https://www.ucl.ac.uk/bartlett/news/2021/may/greenhouse-gas-removal-programme-wins-ps30million-government-funding** (accessed 10.14.25).

United Nations, 1998. Kyoto Protocol to the United Nations Framework Convention on Climate Change.

Wang, N., Akimoto, K., Nemet, G.F., 2021.
What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects. Energy Policy 158, 112546.
https://doi.org/10.1016/j.enpol.2021.112546

Wilson, C., De Stercke, S., Zimm, C., 2023.
Building back better: Granular energy technologies in green recovery funding programs. Joule 7, 1206–1226.
https://doi.org/10.1016/j.joule.2023.05.012

Appendix A: List of acronyms

BECCS – Bioenergy with Carbon Capture and Storage

CAGR – Compound Annual Growth Rate

CB6 – The CCC's 6th Carbon Budget analysis

CB7 – The CCC's 7th Carbon Budget analysis

CCS – Carbon Capture and Storage

CCU – Carbon Capture and Utilisation

CCUS – Carbon Capture, Utilisation and Storage

CDR – Carbon Dioxide Removal

DACCS – Direct Air Carbon Capture and Storage FR – Failure Rates

GHG – Greenhouse Gases

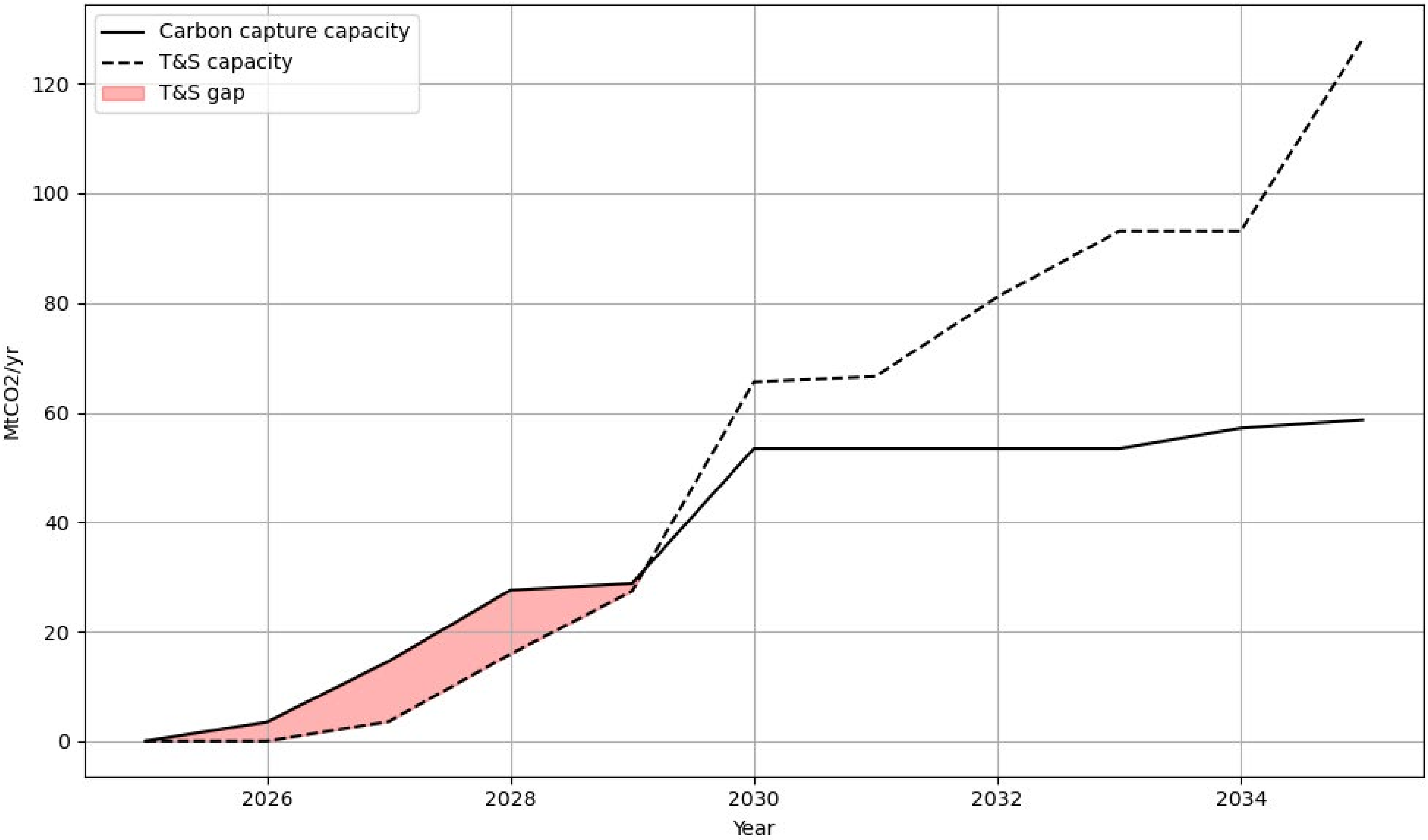
Mit-CCS – Mitigation options with Carbon Capture and Storage

MtCO2(e) – Million Tonnes of Carbon Dioxide (equivalent)

NETs – Negative Emission Technologies

Appendix B: The (mis)alignment of carbon capture and transport-and-storage (T&S) plans

Figure 6: Cumulative planned carbon capture capacity (unbroken line) compared with cumulative planned T&S capacity (dashed line) from 2025-2035.



The red shaded area represents carbon capture capacity that will not be able to be met by planned T&S capacity, i.e. the “T&S gap”.

Mit-CCS and CDR-CCD technologies all rely on a three-part downstream supply chain to provide capture, transport and storage. If these sections do not develop in step with one another, then the overall supply chain risks breaking down. Figure 6 plots a comparison of carbon capture project capacity in the UK, as seen in previous sections, alongside planned T&S capacity as per IEA data (IEA, 2025).

Note that plans without an assumed operational date are excluded. Assessing carbon capture capacity in isolation only presents part of the supply chain picture. By considering T&S capacity development alongside carbon capture projects we are better able to discuss the full supply chain and derive implications for emissions reductions, investment risk and future market development.

Planned T&S projects currently lag planned capacity for carbon capture projects in the first years of deployment (from 2026-2029). The T&S gap (highlighted red in Figure 6) represents 3.5 Mt CO2/yr in 2026, rising to 11 and 11.5 $MtCO_2$/yr in 2027 and 2028, respectively. This is significant as it represents 40% of total capture capacity. The gap is much smaller in 2029, sitting at 1.5 Mt CO2. After 2029, the growth of T&S storage projects outstrips the pace of planned capture projects. By 2035, this discrepancy suggests that up to 55% of T&S project could fail and still service the expected capture capacity.

Developing huge networks of infrastructure, such as carbon capture plants and the requisite T&S capacity, will always have inherent uncertainty in project planning. Thus, it is not unusual that these capacities do not match up perfectly. However, there's a two-sided risk that needs to be managed, as each stakeholder group needs to know (i) that they will be able to offload their CO2 and (ii) that there will be a customer to use the expensive pipeline infrastructure you're building, highlighting the need for greater cross-chain de-risking.

Delays in the connection of carbon capture projects to T&S capacity creates volume risks for T&S providers. There are large economies of scale in pipeline construction, but a final investment decision on building transport infrastructure (and therefore its size and capacity) will be needed before exact carbon capture volumes will be known, representing a financial risk for T&S companies (Bellona Europa, 2021), On the other hand, if T&S capacity is too small, then CO2 that is captured cannot be transported to long-term geological storage, then it may have to be emitted into the atmosphere, leading to an additional 27.5 MtCO2 of carbon being emitted by the UK. However, the greater risk comes from impacts to market integrity in a period when building investor confidence is crucial to establishing a functioning CCS market. If costly carbon capture infrastructure is built and underutilised, this represents a stranded asset and lost revenue for investors. Not only does this drive up costs for existing projects (Middleton and Yaw, 2018), but uncertainty over market development could damage investor confidence and lead to funding for future projects being pulled, or ultimately cancelled – risking their contribution to the UK's emissions reductions targets.

Government support is clearly needed to manage cross-chain risk and ensure that all stages of the CCS process continue to develop and be deployed in-step. There are several means to ensure this. First, ensuring and incentivising that UK CCS companies (at all stages in the chain) have access to international networks can allow for any imbalance between CO2 capture and T&S capacity to potentially be offset by spare capacity elsewhere (and vice versa). Second, greater market coordination can ensure that one part of the CCS chain is not expected to develop at a faster pace than another.

Finally, in the absence of an established market, some degree of risk may have to be absorbed by the state. Currently, there is little incentive for CO2 removal and storage beyond voluntary offsetting payments, which is wholly insufficient to build a market from scratch. The UK Government is currently in the process of establishing sector-specific (T&S, industrial carbon capture, hydrogen, power and BECCS, and greenhouse gas removal) policy mechanisms to ensure revenues are stable during these early years of deployment, via bespoke Contracts for Difference, high impact, low probability risk insurance and payment mechanisms (CCUS Business Models and Building Viable CCUS Projects, 2023). Furthermore, the Government's "track" approach to industrial decarbonisation also aims to limit these risks by setting in place key locations where they will support projects and developing business models that include both capture and the requisite T&S infrastructure.

Specialised policy mechanisms such as these should ensure investor confidence by increasing the reliability of revenue streams, especially in the context of a mismatch of timing between the delivery of different infrastructures. They allow investors in T&S to proceed without the need for already established carbon capture projects (and vice versa) and ensure that revenues are commensurate with the risks that firms take.

The Priestley Centre's Climate Evidence Unit provides independent insight to inform the delivery of a climate resilient, decarbonised future. It brings together world-leading experts from the University of Leeds to deliver timely and robust evidence that can inform climate action.

The Priestley Centre for Climate Futures is a leading climate change centre based at the University of Leeds.

For more information, including how to work with us, visit **climate.leeds.ac.uk.**

Disclaimer

The information and recommendations presented in this work are based on the current evidence in the public domain on the date of publication. Any substantial progression in the underpinning evidence could therefore lead to the findings and recommendations of this work being outdated or irrelevant.

The findings and recommendations do not indicate a view or position taken by the University of Leeds.

Funding statement

The Climate Evidence Unit is supported by Research England funding.

Elliott Johnson, Oliver Broad, Paul Brockway (2025): Carbon capture and storage in the UK: deployment requirements and risks. White Rose Libraries.
https://doi.org/10.48785/100/412

UNIVERSITY OF LEEDS

Priestley Centre for Climate Futures