Institute for Energy Economics and Financial Analysis

UK Carbon Capture Policy: Out of Step With Net-Zero Goals

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Key Findings

UK government incentives for carbon capture are disproportionately supporting the development of blue hydrogen projects, increasing long-term reliance on fossil gas within the UK energy mix.

Support for abating emissions from the UK's existing gas and bioenergy power stations is severely lacking, potentially putting at risk the UK's target to decarbonise the power sector by 2035.

Government-sponsored projects are pointed towards oil and gas owners, accounting for 78% of the proposed emissions capture and presumably the majority of the £20 billion in public support available.

Executive Summary

Carbon capture and storage (CCS) is increasingly being championed by various stakeholders as a climate solution to support the decarbonisation of fossil fuels, be they governments with emissions reduction targets, project owners seeking to reduce emissions or fossil fuel producers supporting the prolonged use of oil and gas and their existing infrastructure.

While big claims are being made regarding CCS's potential to help with decarbonisation, the underlying evidence from smaller scale demonstration projects is far less convincing. There exist significant technical, economic and environmental risks across almost all CCS applications.[1]

Despite this, the UK government has pledged £20 billion in public money over the next 20 years to support the country's CCS ambition. A high-risk pillar of the UK's decarbonisation strategy, it is based on the forecast that around 22 million tonnes of carbon dioxide ($MtCO_2$) will be required to be captured per annum by 2030, rising to 104 $MtCO_2$ by 2050, in support of the nation's net-zero commitments.[2]

The UK government has initially chosen eight CCS projects across the HyNet and the East Coast Cluster to prioritise over others as part of the 'Track 1' support. Presently, they are in bilateral dialogue to examine and consider the specific financial support the government will offer to each project to help kick-start a UK CCS market.

On closer examination however, the Track 1 projects are falling short of the UK's CCS requirements as set out by the Climate Change Committee (CCC) in its Sixth Carbon Budget.[3] An overwhelming majority of the carbon to be captured is generated by expensive, fossil gas-based blue hydrogen projects, which, in the short term, will account for 4.5 times more captured CO_2 than the CCC's 2030 requirements.

This is coupled with a severe lack of support for decarbonising electricity supply or retrofitting gas-fired power generation with CCS. Currently, Track 1 projects will meet only 16% of the 12.4 $MtCO_2$ per annum required to support the decarbonisation of electricity supply by 2030, putting at risk the target that all gas power generation will be abated by 2035[4] or that existing gas power stations will have CCS retrofitted.

Government support of new-build gas power generation with CCS, namely the Net Zero Teesside project, is also worrisome. The CCC recognises that the UK will continue to rely on gas power generation as the country progresses to net zero over the coming decades while lower carbon electricity capacity increases. It is unlikely that CCS subsidies were intended to support additional

[1] IEEFA. The carbon capture crux: Lessons learned. September 2022.
[2] Climate Change Committee. Sixth Carbon Budget. December 2020.
[3] Ibid.
[4] Ibid.

gas-fired power stations, when simultaneously the UK is working to expand its renewable and nuclear power generation capacity in a bid to reduce its reliance on gas.

It has often been argued[5] that CCS is being used by the oil and gas industry to justify and support the continued use of fossil fuels within the global energy mix, and UK activity seems to support this. Of the Track 1 projects proposed for support, some 81% of captured emissions are proposed to come from processes that require long-term fossil gas use. Using our estimates[6] of the volumes of carbon to be captured during the initial and ramp-up phases of the Track 1-supported projects, 78% of carbon capture will come from projects owned by oil and gas companies.

While we cannot comment on the UK government's decision-making process to initially support such a high proportion of fossil-based CCS, we can make some observations. Firstly, when examining the information available and the progress of proposed CCS projects, it appears that the oil and gas sponsors are better organised and further progressed with their plans. By definition they are highly motivated—continued and long-term commitment to fossil gas use is core to their business model—but they are also well funded, in addition to being experienced and sophisticated lobbyists.

[5] Reuters. Analysis-Sunrise or another false dawn for technology to bury emissions? August 2021.
[6] IEEFA analysis of publicly available information gained from project and company websites, in addition to news outlets.

Carbon Capture, Utilisation and Storage: A Long History of Supporting Increased Oil and Gas Extraction

Carbon capture, utilisation and storage (CCUS) refers to a suite of technologies that aim to capture carbon from large sources, such as gas fields, power generation facilities or industrial plants that use fossil fuels or biomass as fuel. The captured carbon is then used on site or at another location—this is the utilisation or the 'U'.

If the carbon is not utilised, we refer to this as CCS. In this scenario, carbon is usually captured as carbon dioxide gas, which is then compressed and transported by pipeline, ship or rail to be injected into deep geological formations. These are either depleted oil and gas reservoirs or saline aquifers, which inject and trap the CO_2 for permanent storage.[7]

Historically, and continuing today, the economic justification for CCUS has centred around supporting oil and gas operations. Carbon capture is used to support fossil gas processing by removing carbon dioxide from gas with high concentrations of CO_2 relative to other gases, which is a requirement to market and sell the gas. The other application is to inject the CO_2 back into oil reservoirs to provide an artificial lift to support increased oil production, which is referred to as enhanced oil recovery or EOR.

CCUS applications have been in existence for many decades, primarily for EOR. The first facility was the Terrell Natural Gas Processing Plant in Texas, U.S., which opened in 1972 to capture and use CO_2 for enhanced oil recovery at a nearby oil field.[8] Presently, there are around 39 commercial facilities in operation capturing 45 $MtCO_2$ per annum, of which 73% is being used for EOR.[9]

In the days before carbon taxes and climate action, there was little discussion or wider application for CCS across power generation or industrial processes. Put simply, there was no economic or climate incentive to manage or reduce carbon emissions from fossil fuel combustion.

Today, many governments have committed to reducing their carbon emissions, with 196 signatories to the Paris climate accord, a legally binding international treaty on climate change to limit global warming.[10] This, coupled with the introduction of net-zero policies across many governments and the continued and growing use of carbon taxes, now provides political and economic stimulus for increased rollout of carbon capture.

[7] International Energy Agency. Carbon Capture, Utilisation and Storage. July 2023.
[8] National Petroleum Council. Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage. December 2019.
[9] IEA. CCUS Projects Database. 2023.
[10] The United Nations. The Paris Agreement: What is the Paris Agreement?

CCS Enters Demonstration Stage for New Applications That Aim to Support Global Decarbonisation

The Intergovernmental Panel on Climate Change (IPCC) states that carbon dioxide removal will be unavoidable to reach net zero.[11] The International Energy Agency (IEA) also supports CCS use, noting that it can be retrofitted to existing power and industrial plants, lowering emissions in hard-to-abate sectors such as cement, iron, steel and chemicals. It also points to it being an enabler for low-carbon hydrogen and for removing CO_2 directly from the atmosphere with bioenergy or direct air capture.[12]

In the IEA's 2023 update of its Net Zero Roadmap, it reduced its forecasts for CCS deployment as a decarbonisation solution by 2030 and 2050, noting that: "The history of CCUS has largely been one of underperformance" and "the current level of annual CO_2 capture of 45 Mt represents only 0.1% of total annual energy sector emissions. This lack of progress has led to progressive downward revisions in the role of CCUS in climate mitigation scenarios, including the 2023 Net Zero Emissions (NZE) Scenario." The IEA now forecasts CCUS contributing less than 5% to required emissions reduction by 2030 and 8% by 2050.[13]

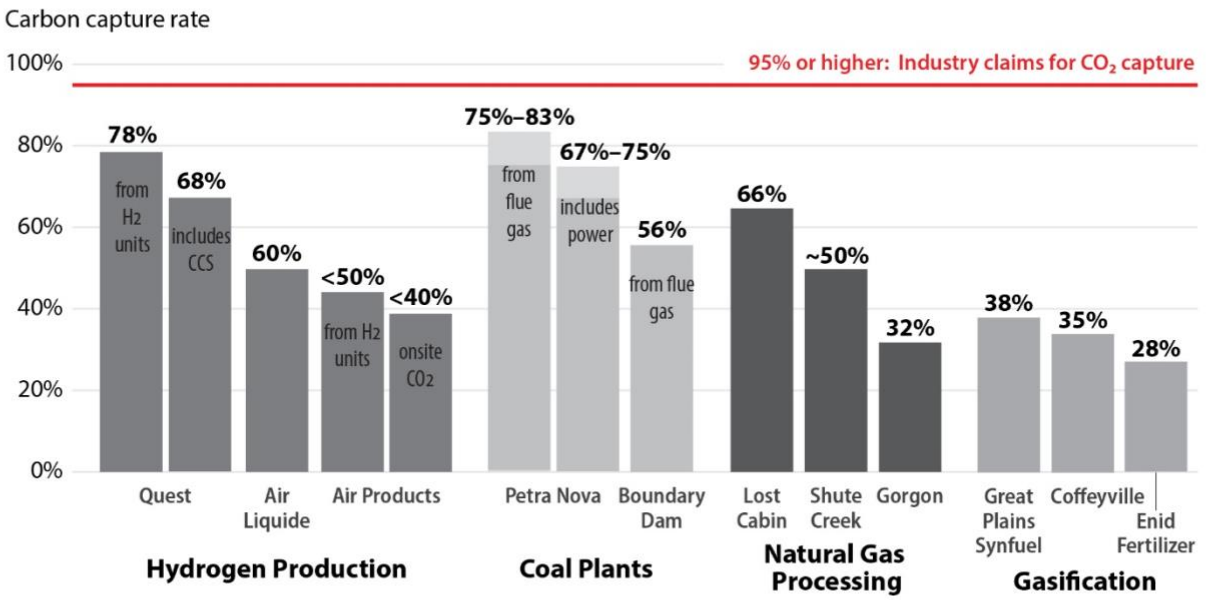
While these organisations recognise the technical, economic and environmental risks associated with CCS application across global industry, these are often underplayed by governments, project owners and industrial stakeholders. High-level momentum surrounding CCS is inherently positive, although once academic papers and CCS project performance are reviewed, carbon capture is costly and technically highly uncertain.

Observed CCS Projects Have Consistently Underperformed

A 2022 IEEFA analysis examined 13 global CCS projects in operation, which were across fossil gas processing, industrial and power sectors and estimated to account for 55% of capture capacity worldwide.[14] The analysis concluded that failed or underperforming projects considerably outnumbered successful experiences, due to lower capture rates being experienced or storage related issues. Figure 1 below is taken from a study published in September 2023 that adds to these findings to show real-world capture rates from 14 projects, all of which have captured far below 95% emissions, a level being claimed by project proponents for blue hydrogen production.[15]

[11] Carbon Brief. In-depth Q&A: The IPCC's sixth assessment on how to tackle climate change. April 2022.
[12] IEA. CCUS in Clean Energy Transitions. 2020.
[13] IEA. Net Zero Roadmap, 2023 Update. September 2023.
[14] IEEFA. The carbon capture crux: Lessons learned. September 2022.
[15] IEEFA. Blue Hydrogen: Not Clean, Not Low Carbon, Not a Solution. September 2023.

Figure 1: CO_2 Real-World Capture Rates at Commercial-Scale Hydrogen Production, Coal-Fired Power Plants, Natural Gas Processing and Gasification Facilities



Source: IEEFA.

While the IEEFA research used a limited sample, predominantly focusing on projects in operation, additional research[16] looking at the number of failures of all the proposed and initiated projects since 2000 conveys, in essence, a similar message. Further, published research by Imperial College London[17] on the capture performance of operating projects since 1996 confirms the underperformance of most projects against their designed or claimed capture capacity.

Technical uncertainties also exist in relation to the ability to store carbon securely. Two storage sites in Norway, Snøhvit and Sleipner, which are often championed as proof-of-concept projects for larger scale offshore carbon storage, have not been without their problems.

- In 1999, three years into Sleipner's storage operations, CO_2 had already risen from its lower-level injection point to the top extent of the storage formation and into a previously unidentified shallow layer. Injected CO_2 began to accumulate in this top layer in unexpectedly large quantities. Had this unknown layer not been geologically bounded, stored CO_2 might have escaped.

- At Snøhvit, problems surfaced merely 18 months into injection operations despite detailed pre-operational field assessment and engineering. The targeted storage site demonstrated acute signs of rejecting the CO_2. A geological structure thought to have 18 years' worth of CO_2 storage capacity was indicating less than six months of further usage potential. This unexpected turn of events baffled scientists and engineers while at the same time jeopardizing the viability of more than US$7 billion of investment in field development and

[16] IOP Publishing. Explaining successful and failed investments in U.S. carbon capture and storage using empirical and expert assessments. 29 December 2020.
[17] ACS Publications. An Estimate of the Amount of Geological CO2 Storage over the Period of 1996–2020. July 2022.

fossil gas liquefaction infrastructure. Emergency remedial actions and permanent long-term alternatives needed to be, and were, identified on short notice and at great cost.[18]

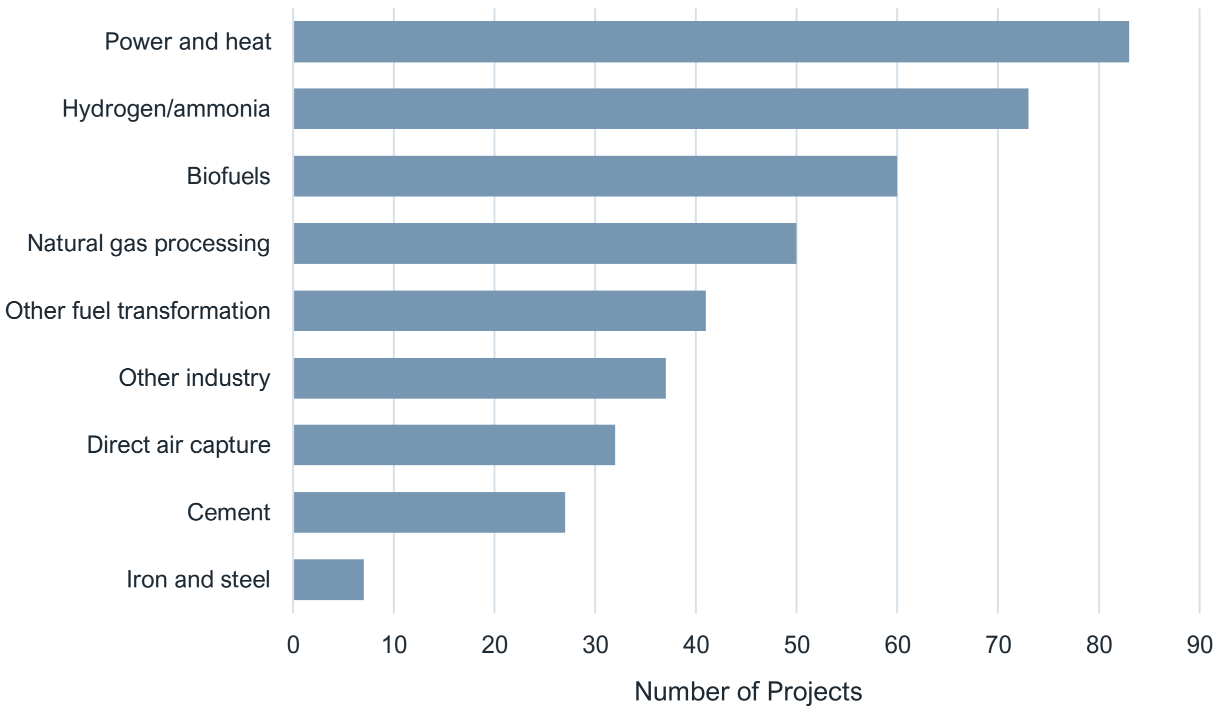
Global Carbon Capture Projects and Outlook

In total, there are 14 countries globally that have carbon capture projects in operation, most of which support the fossil fuel production industry. From a geographic perspective, over half of the 45 $MtCO_2$ of carbon capture per annum is contained within North America, namely the U.S., which accounts for around 21 $MtCO_2$ per annum (pa). Single large-scale projects at the Santos oil field in Brazil (8.7 $MtCO_2$pa), Gorgon in Australia (4 $MtCO_2$pa[19,20]) and Qatar LNG (2.1 $MtCO_2$pa) account for a further 32% of global capture.

Despite the historical dominance of projects centred around fossil fuel extraction, there are in operation a small number of CCS projects supporting biofuels, iron and steel, power and heat, and hydrogen production. While its use across these other industries is relatively small at around 7 $MtCO_2$, or 16% of global carbon capture, there is an increasing number of potential projects that have been announced that will seek to capture carbon from a wider variety of high-emissions sectors in the future, in pursuit of decarbonisation goals.

[18] IEEFA. Norway's Sleipner and Snøhvit CCS: Industry models or cautionary tales? June 2023.
[19] Announced high capacity as per the IEA CCUS Projects Database, although actual capture rates can be much lower than estimated.
[20] IEEFA. Gorgon Carbon Capture and Storage: The Sting in the Tail. April 2022.

Figure 2: Global Carbon Capture Announced Projects



Source: IEA CCUS Projects Database.

According to the IEA CCUS Projects Database, there has been an exponential rise in the number of announced carbon capture projects globally. Since 1991, there have been 573 projects declared, of which 83% have occurred over the past five years (2018-2023 year to date) and 355, or 62%, during 2021 and 2022 alone.

While there is potential for CCS use across hard-to-abate sectors, only 8% of projects support iron, steel and cement production. Most proposed projects are centred around decarbonising fossil fuels. CCS projects in the power and heat sector are predominantly for reducing emissions at coal- and gas-fired power stations, while those for hydrogen production are 'blue', i.e. produced using fossil gas. CCS projects for fossil gas processing support gas production and other fuel transformation centres around lowering emissions from refinery production. Collectively, fossil fuel-related sectors account for 60% of proposed CCS projects.

From a geographic perspective, the explosion in global CCS activity is centred around North America and Europe, which account for 72% of announced projects. This is in part due to the increased policy support and incentives being promoted by host governments. In North America, the most notable development has been in the U.S. with the introduction of the Inflation Reduction Act, complemented by Canada's 2022 Federal Budget commitments, both of which provide tax credits for CCS investment and operations.

Within Europe, the Danish government committed €5 billion for CCS over the next ten years and the Dutch government is supporting the sector with €13 billion of public funds. [21] Many other countries in Europe are becoming increasingly active due to the EU Innovation Funds granting programme, which has already provided billions of euros in grants to multiple projects over three calls since 2021. A fourth call for project proposals is expected to be announced at the end of this year, with a budget of approximately €4 billion to be spent supporting industrial decarbonisation.[22]

In the UK, during the Spring Budget 2023 the UK Chancellor Jeremy Hunt committed to providing up to £20 billion in funding over 20 years for the early development of CCUS to help meet the government's climate commitments.[23]

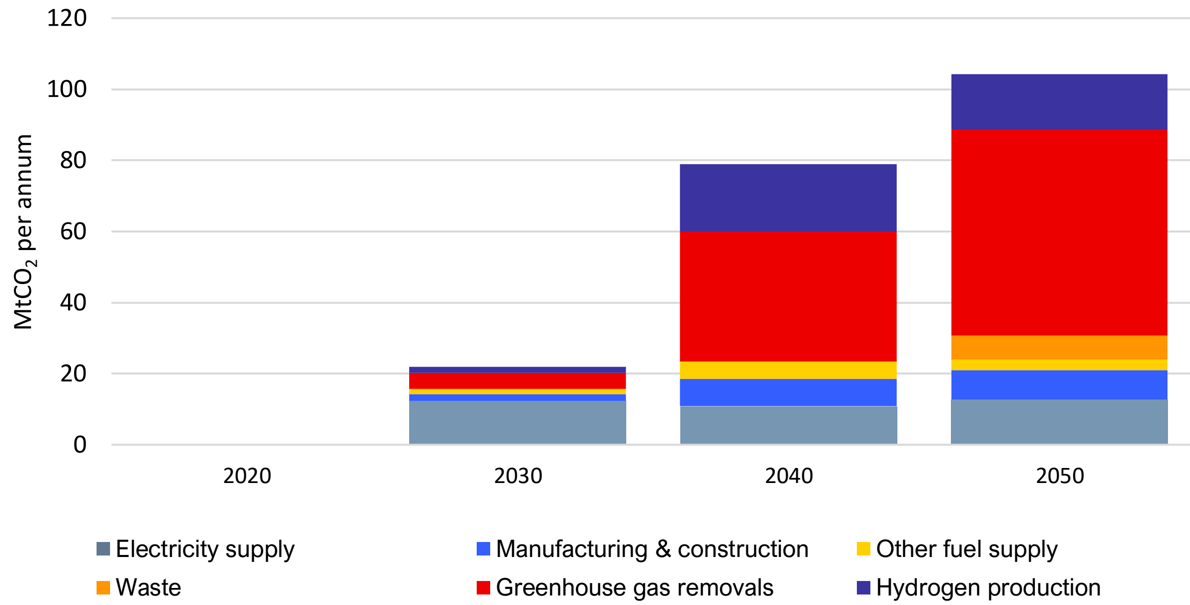
The UK's CCS Ambitions

The Climate Change Act was introduced in 2008, and this legislation commits the UK government by law to reducing greenhouse gas emissions by at least 100% relative to 1990 levels, or "net zero" by 2050. The act also established the CCC, a non-departmental public body sponsored by the Department for Energy Security and Net Zero, to ensure that emissions targets are evidence-based and independently assessed.[24] In addition to its oversight role, the CCC has produced a series of Carbon Budget advice reports that provide guidance to government ministers on the volume of greenhouse gases the UK can emit to meet net zero by 2050.

The Sixth Carbon Budget was released in December 2020—which means some elements are beginning to look outdated—but it remains the most recent edition of the CCC's guidance, with the next carbon budget due to be published in 2025. The report examines all the greenhouse emissions sources from production and consumption within the UK, and it provides targets on emissions reduction through a variety of methods such as fuel switching, increased low-carbon electricity supply, consumption and behavioural change, in addition to CO_2 capture and other emissions, or CCS.

[21] Global CCS Institute. Carbon Capture and Storage Experiencing Record Growth as Countries Strive to Meet Global Climate Goals. October 2022.
[22] European Commission. EU invests €3.6 billion of emissions trading revenues in innovative clean tech projects. July 2023.
[23] HM Treasury. Policy Paper, Spring Budget 2023. March 2023.
[24] Climate Change Committee. What is climate change? A legal duty to act.

Figure 3: CCC Sixth Carbon Budget Carbon Capture Requirements by Sector



Source: CCC Sixth Carbon Budget.

The CCC champions CCS as "essential" to reducing emissions in the UK, claiming that without its use, achieving net zero will take longer. Parts of the manufacturing, refining and energy from waste (EfW) sectors require CCS to decarbonise as there are no other viable low-carbon alternatives. Reliance on natural removals alone, the CCC argues, would require an increasing amount of natural carbon stocks such as forests and peatlands, increasing the area in the UK devoted to sequestration.[25]

In relation to carbon capture demand, the CCC estimated that 104 $MtCO_2$ per annum would be required by 2050 within its Balanced Net Zero Pathway, its baseline case. This equates to 18% of emissions reductions coming from CCS by 2050. As of today, no CCS facilities are operating in the UK, although this is required to grow to 22 $MtCO_2$ per annum by 2030, increasing to 79 $MtCO_2$ by 2040. Come 2030, 57% of CCS is expected to be used to support electricity production, namely gas-fired power generation with CCS, with a further 21% supporting greenhouse gas removals, namely bioenergy with CCS (BECCS) from power, EfW, hydrogen and biofuels.[26]

By 2050, some 56% of CCS is to be used in greenhouse gas removals, primarily through the combustion of biomass; a further 15% would support blue hydrogen production, while 12% would be used with gas in the power sector.[27]

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[25] Climate Change Committee. Sixth Carbon Budget. December 2020, p. 90.
[26] Climate Change Committee. Sixth Carbon Budget. December 2020.
[27] Climate Change Committee. Sixth Carbon Budget. December 2020, p. 72.

UK Government Support for Carbon Capture

Successive UK governments have sought to support CCS, albeit this has blown hot and cold over the previous decades. In the 2003 Energy White Paper, carbon capture and storage was first recognised as a "promising way forward" to creating a low-carbon economy,[28] and in 2007 the Department for Business, Enterprise and Regulatory Reform launched a competition for industry to design, construct and operate the UK's first commercial-scale CCS demonstration project at a coal-fired power station.[29]

In 2010, a spending review made available £1 billion for the project, yet in 2011 the project was cancelled, only for the Department of Energy and Climate Change to launch a new CCS strategy and second competition in 2012. This was also cancelled in 2015/16[30] due to costs being too high, projects not leading to further investment in CCS and the belief that there were better uses for the £1 billion.[31]

Recognising the need for potential intervention to support the future of CCS development, the CCS Cost Reduction Task Force was set up in 2012. In its 2013 report, it concluded that the UK would benefit from lower cost deployment by investing in CO_2 storage clusters supplying multiple CO_2 sites, investing in larger facilities and reducing the cost of project capital by reducing risk and improving investor confidence.[32]

In 2017, the UK government went on to launch The Clean Growth Strategy, which outlined how the UK would meet its decarbonisation targets. It also provided £100 million for industrial innovation to lower CCS costs, a CCS Ministerial Council to review progress and a CCS Cost Challenge Taskforce to provide advice on lower cost deployment.[33] In the same year, the Carbon Capture and Utilisation Demonstration innovation programme was launched, allocating £20 million to support demonstration projects, while in 2018 the Department for Business, Energy and Industrial Strategy launched a £15 million innovation programme.[34]

Momentum really started to build in 2019 with the launch of two decarbonisation funds for capital expenditure totalling £485 million.[35] In 2020, the introduction of the Carbon Capture and Storage Infrastructure Fund (CIF) confirmed the allocation of £1 billion to support two CCS clusters by the mid-2020s and four by 2030, with an ambition to capture 10 $MtCO_2$/year by then.[36]

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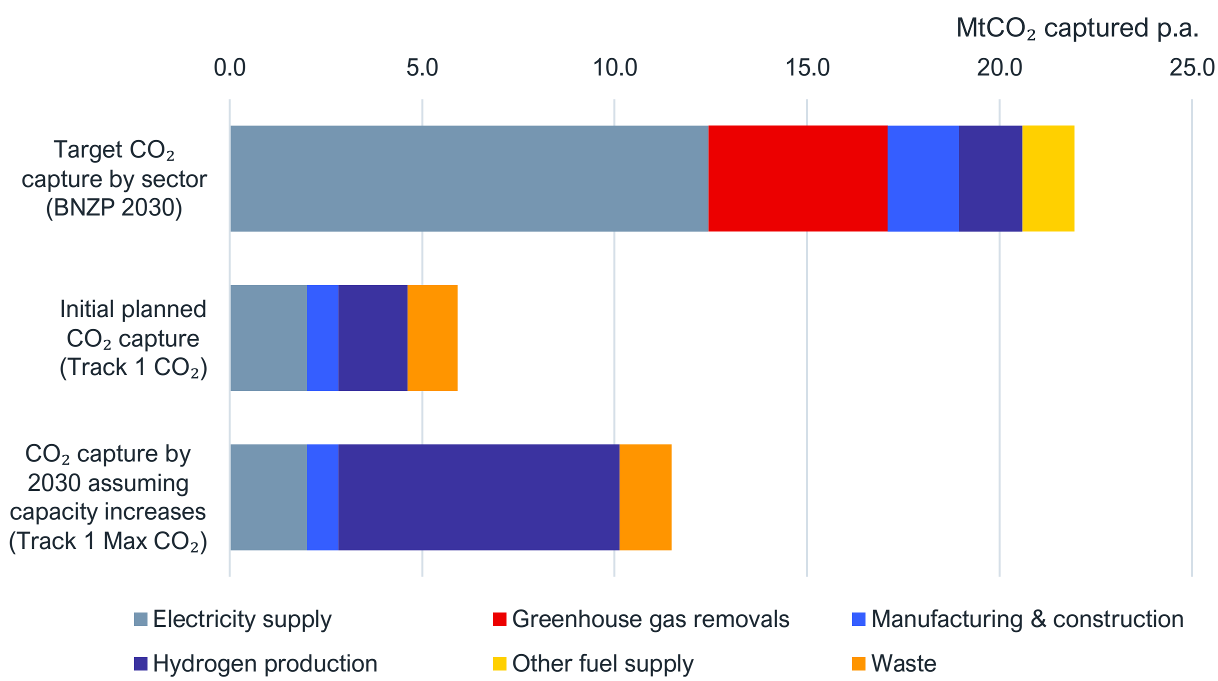
[28] Department of Trade and Industry. Energy White Paper: Our energy future – creating a low carbon economy. February 2003.
[29] Department for Business, Energy and Industrial Strategy. Carbon capture and storage: the second competition for government support. January 2017.
[30] Commons Library Briefing. Carbon capture usage and storage. March 2020.
[31] Department for Business, Energy and Industrial Strategy. Carbon capture and storage: the second competition for government support. January 2017.
[32] Department of Energy and Climate Change. CCS Cost Reduction Task Force: Final Report. May 2013.
[33] Commons Library Briefing. Carbon capture usage and storage. March 2020.
[34] Department for Business, Energy and Industrial Strategy. CCUS Innovation Programme. June 2017.
[35] Commons Library Briefing. Carbon capture usage and storage. March 2020.
[36] Gov.UK. Policy Paper, The Carbon Capture and Storage Infrastructure Fund: an update on its design. December 2022.

The CIF is a material government policy that has been reviewing a number of regional clusters and specific projects within the UK under its sequencing process. In 2021—as part of the Phase 1, Track 1 projects—the government shortlisted 20 projects contained within two regional clusters: HyNet centred around Liverpool Bay and the East Coast Cluster in Teesside and the Humber region. In March 2023, eight of the projects contained within the two clusters were selected to proceed to negotiations for support through the relevant business models, referred to as the Phase 2, Track 1 projects.[37]

A Review of the UK's Track 1 CCS Projects

Examining the Track 1 projects is challenging as there are varying degrees of data and information available in the public domain relating to their commercial and technical characteristics. Our analysis has highlighted that the Track 1 projects will be delivered in phases, the first being used to initiate CCS across several different industrial applications and the second for scaling operations.

Figure 4: Climate Change Committee's Balanced Net Zero Pathway 2030 CCS Requirements by Sector Relative to Track 1 Projects ($MtCO_2$ Capture per Annum)



Sources: Climate Change Committee Sixth Carbon Budget, IEEFA analysis.

[37] Gov.UK. Cluster sequencing Phase-2: Track-1 project negotiation list. March 2023.

In total, the eight projects are expected to capture ~6 $MtCO_2$ per annum during their initial phase, or 27% of the CCC 2030 forecast. Assuming capacity is increased from follow-on phases before the end of the decade, the projects will continue to fall short, meeting only 52% of the carbon capture target.

Material underperformance is going to occur in the decarbonisation of electricity supply, which is currently forecasted to meet 16% of the target, while greenhouse gas removals, the second largest industrial area, stands at 14%. Collectively the two sectors represent 78% of the 2030 CCS target, of which only 16% is being supported through Track 1.

While there is underperformance in some sectors, there is overperformance in waste, which currently supports ~0.7 $MtCO_2$ per annum from EfW projects. Targets for the sector are at zero for 2030 and 2040, and they feature in the 2050 forecast at 7 $MtCO_2$ per annum. Total emissions from EfW facilities are expected to be ~20 $MtCO_2$ once all 69 facilities in operation and development are completed, prior to any carbon capture.[38]

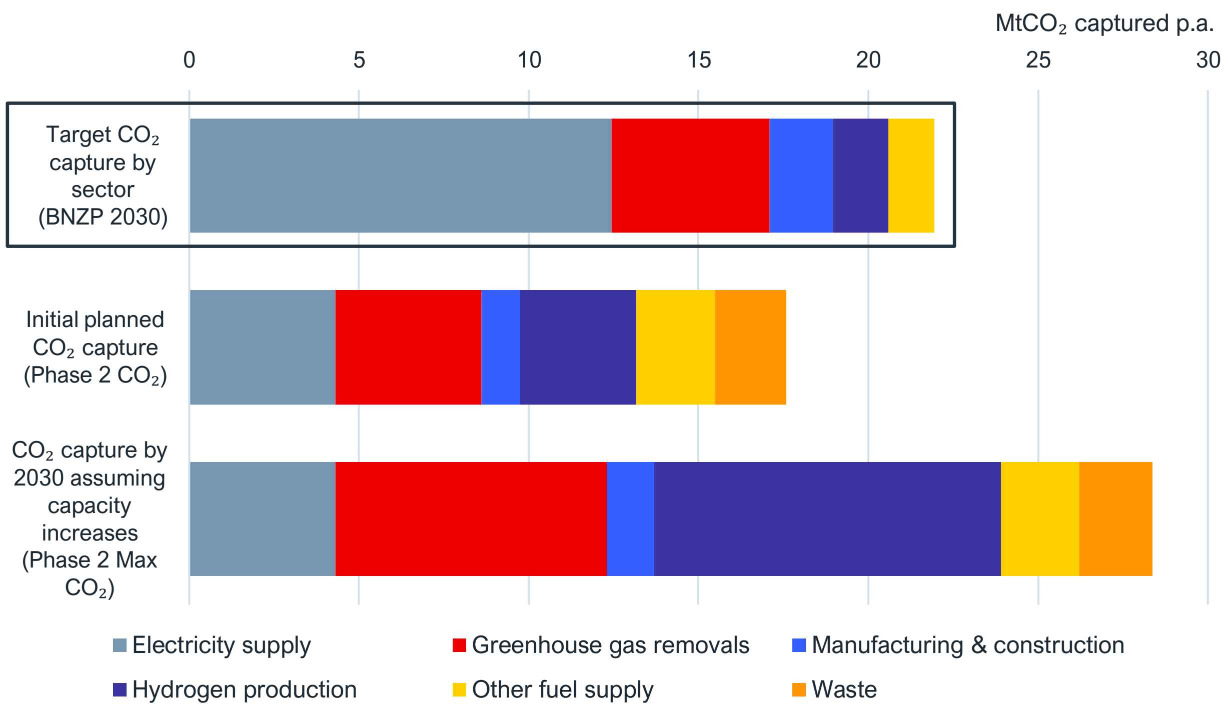
Overperformance is also being exhibited in hydrogen production, which—based on initial phase capture—will deliver 110% of its target. Assuming these facilities expand capacity in follow-on phases, this will increase to 444% of the CCC 1.6 $MtCO_2$ per annum ambition. Overall, of the ~11 $MtCO_2$ per annum of potential capture across Track 1 projects, fossil-based hydrogen production represents 64%.

> **Overall, of the ~11 $MtCO_2$ per annum of potential capture across Track 1 projects, fossil-based hydrogen production represents 64%.**

What is clear is that the UK government will not meet its 2030 CCS target by supporting the Track 1 projects alone and will likely be required to continue dialogue and support additional projects. Assuming the government were to include the 20 projects outlined in the initial Phase 1, Track 1 announcement, the potential to meet the CCC near-term target would be greatly increased. Assuming all project phases are completed prior to 2030, overall emissions capture would meet 93% of the CCC target.

[38] Catapult Energy Systems. Energy from Waste Plants with Carbon Capture. May 2020.

Figure 5: Climate Change Committee's Balanced Net Zero Pathway 2030 CCS Requirements by Sector Relative to Phase 1, Track 1 Projects ($MtCO_2$ Capture per Annum)



Sources: Climate Change Committee Sixth Carbon Budget, IEEFA analysis.

While championing a larger number of projects from the initial selection gets close to the overall capture target, closer examination demonstrates enormous gaps in sector-specific decarbonisation.

Electricity supply improves with the addition of two projects, which double capture to 4.3 $MtCO_2$ but leave the sector 70% short of target. This is especially worrisome given that there is an ambition to have no unabated gas-fired power generation in the UK by 2035, by which time remaining gas power plants must use CCS. Current trajectories suggest that the UK government is going to fall way short of its aims.

Greenhouse gas removals continue to be neglected, with few projects being supported other than the biogenic fuel component of EfW schemes. Up until the announcement in March 2023 when the eight projects contained in Phase 2, Track 1 were confirmed, a parallel process was in place examining power BECCS projects. While none were selected, the UK government has entered formal bilateral discussions with project owners to move potential projects forward.[39]

Most notably, the largest and most material potential BECCS project is the Drax Power Station, which—if it were to proceed successfully with its first phase—claims to have the potential to capture

[39] Drax Investor Relations. Drax enters formal discussions with UK Government on large-scale Power BECCS. March 2023.

4.3 $MtCO_2$ per annum, or 92% of the CCC target for greenhouse gas removals in 2030. According to project proponents, the addition of phase two of the project could capture 8 $MtCO_2$ per annum, or 172% of the target.

Given the future growth targets of greenhouse gas removals, which is to reach 58 $MtCO_2$ per annum by 2050 and is by far the largest sector, the UK government may feel it has little choice but to support the Drax Power Station to avoid falling short of its commitments. However, given the historic failure of CCS for coal power and the lack of operational demonstration for BECCS technology, in IEEFA's opinion any public subsidy or price support should come with stringent performance conditions to ensure that claimed carbon capture and storage rates are met. The risk-adjusted cost of such a project should also be compared with other carbon mitigation options, to achieve the best value for taxpayers.

While the eight projects referenced are the current focus of government negotiations, the UK government has announced that it intends to expand Track 1 projects within both clusters, while also introducing a Track 2 to identify two additional clusters to support an increased ambition of 20-30 $MtCO_2$ per annum of capture by 2030.[40] Given the carbon volumes that are due to be captured in the Track 1 projects, the UK government will have to expand its support across many more projects than the current eight.

This has already started to happen as witnessed by the announcement in July 2023 that the Acorn and Viking CCS projects would move into the Track 2 support scheme.[41] We have not included either cluster in our initial analysis as while the announcement has indicated potential support for transportation and storage sites, there has been no indication as to which capture projects will be included.

According to the IEA database,[42] there are 10 prospective carbon capture projects within Acorn and Viking that have the potential to capture ~19 $MtCO_2$ across all project phases. Around 44% or, 8.5 $MtCO_2$, is from power generation facilities, excluding the potential new-build combined-cycle gas turbine facility at Stallingborough.[43] Support for the power projects, as opposed to the hydrogen and refining that make up the balance of potential emissions capture, would reverse the current gap in decarbonising power supply as per the CCC projections.

[40] Gov.UK. Cluster sequencing Phase-2: Track-1 project negotiation list. March 2023.
[41] Gov.UK. Hundreds of new North Sea oil and gas licences to boost British energy independence and grow the economy. July 2023.
[42] Announced high capacity as per the IEA CCUS Projects Database, although actual capture rates can be much lower than estimated.
[43] RWE. RWE announces development proposals for three new carbon capture projects across the UK. May 2023.

Admittedly, the CCC recognises that on the path to net zero there will be over and underperformance across different sectors through the journey. After all, it argues, the overall aim is to continually reduce emissions to reach that point. However, the government is currently off track in supporting emissions reductions in key industrial sectors and is on a trajectory to miss net-zero targets in the short to medium term while additionally providing disproportionate support to projects that support the long-term use of fossil fuels.

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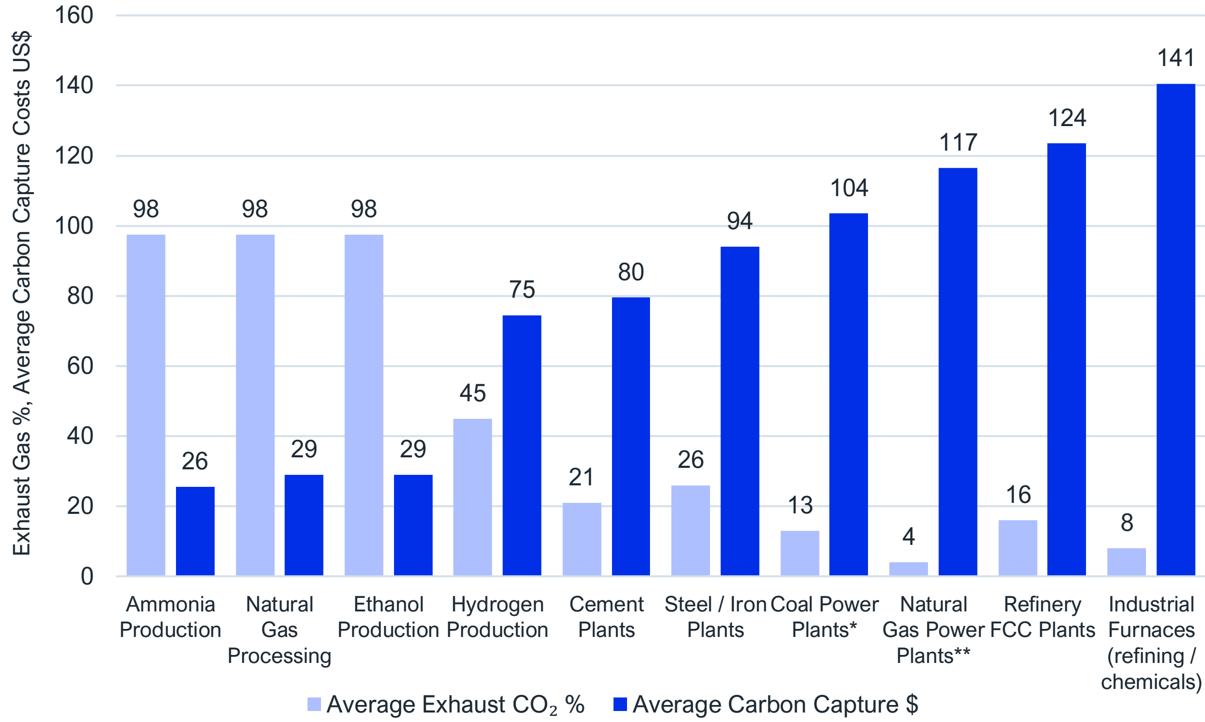
The Economics of Carbon Capture

Carbon capture is normally split into two phases. Firstly, there is the capture of the carbon from the industrial process and secondly, the transportation of the carbon to a storage facility whereupon it is injected into an underground reservoir. The most challenging and costly component of the process is the first phase, or the capture. This is due to the variations in the concentration of exhaust CO_2 from combustion processes. In applications where the CO_2 concentration is high, the capture process is much more effective, which in turn reduces the process infrastructure required, energy input and cost per tonne of CO_2 captured.

Figure 6: Average CO_2 Exhaust Percentage Versus Average Carbon Capture Cost per Tonne (US$)



Source: National Petroleum Council.

According to the National Petroleum Council (NPC),[44] the capture costs across different industrial applications vary considerably. At the lower end of the cost scale, for ammonia production, fossil gas processing and ethanol production with high exhaust concentrations of 98%, the cost of capture is under US$30 per $MtCO_2$.

The balance of industrial applications does not benefit from the same high CO_2 concentrations and consequently their capture costs rise significantly. Hydrogen production with exhaust CO_2 at 45% increases the capture cost to US$75 per $MtCO_2$, whereas decarbonising coal power, fossil gas power, refineries and industrial furnaces is expected to cost over US$100 per $MtCO_2$.

While the NPC analysis did not include BECCS, the Global CCS Institute in a 2019 literature review[45] highlights that for BECCS using combustion, or that proposed by the Drax Power Station, the average cost is US$188 per $MtCO^2$ and is one of the highest-cost CCS applications.

[44] National Petroleum Council. Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage. 2021 update, chapter 2.
[45] Global CCS Institute. Bioenergy and Carbon Capture and Storage, 2019 Perspective.

Our analysis of the NPC data uses an average cost of capture based on its high and low estimates. It should be noted that cost estimates for carbon capture will vary considerably as for many industrial applications there are few if any demonstrator or large-scale projects currently in operation. This effectively means that the proposed technology is untested, while capital and operational costs are best estimates. Additionally, not all projects or applications will be the same as there will be differences in construction and operational costs across different facilities, in addition to variances in capture effectiveness.

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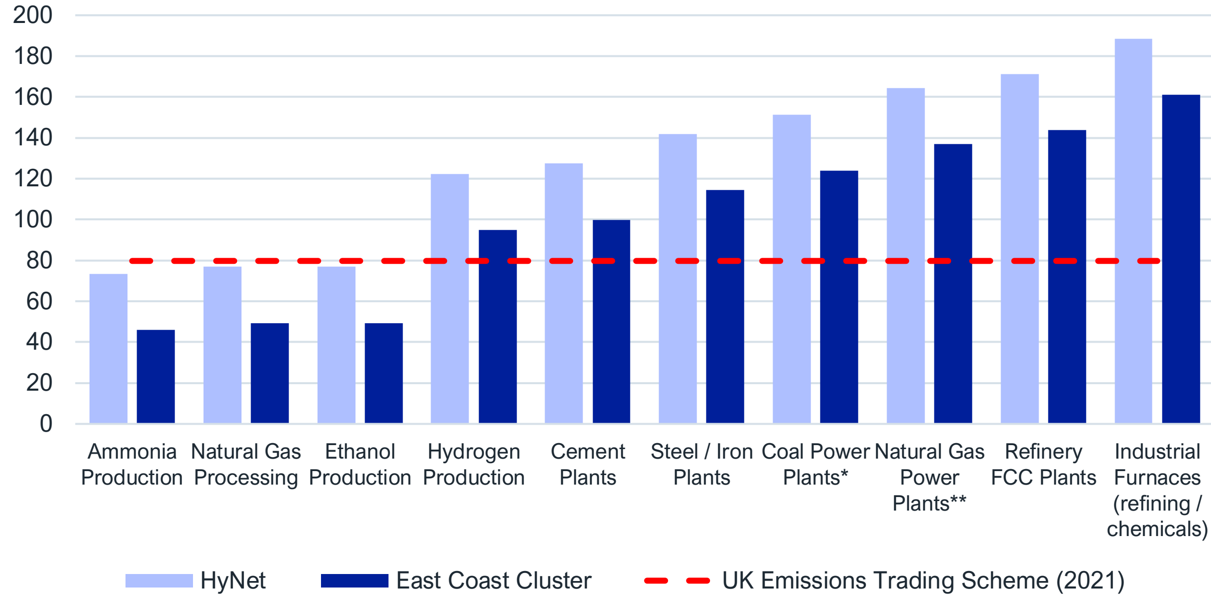
While the outline of capture costs has been reviewed by application, transport and storage (T&S) costs are determined by geographic and site-specific considerations. The proximity to storage sites or facilities will influence pipeline or other transportation requirements and costs, in addition to volumes and injection requirements at the storage facility. As many T&S projects expect to utilise existing oil- and gas-related infrastructure, this will impact construction costs as efficiencies are expected to be realised.

Within the UK, CCS projects are concentrated around clusters where several high-carbon industrial emitters plan to share transport pipelines and storage facilities. The two clusters currently being reviewed to receive government support through Track 1 will utilise the Endurance storage facility in the North Sea and the Hamilton facility at Liverpool Bay on the west coast of the UK. While these projects are still in the engineering phase, data availability relating to potential costs is currently limited.

An analysis by the Clean Air Task Force, however, has provided estimates for T&S costs for CCS projects surrounding the Endurance and Hamilton facilities, which are €19 per $MtCO_2$ and between €32-57 per $MtCO_2$ respectively.[46] Similar to the cost estimates for carbon capture, the T&S cost will also vary considerably, and in simple terms CCS cost analysis at this point in the UK market is opaque and subject to a high degree of uncertainty.

[46] Clean Air Task Force. The cost of carbon capture and storage in Europe.

Figure 7: CCS Capture and Storage Cost per Tonne (US$) by Industry and UK Cluster



Sources: National Petroleum Council, S&P Global, Clean Air Task Force, IEEFA analysis.

Although cost estimates will be project-specific and subject to wide variances, based on the analysed data it is apparent that most projects in industrial sectors across the Track 1 clusters, HyNet and the East Coast Cluster will require some kind of financial support to be viable. When the costs of full chain CCS are compared to the UK Emissions Trading Scheme price, or the effective carbon price, it is evident that many sectors will require support to initiate a UK carbon capture market.

The UK government in December 2022[47] produced outline guidance relating to the ongoing support that it would provide to carbon capture, usage and storage projects. The projects identified during Track 1 of the CCUS Cluster Sequencing process will undergo further due diligence and commercial negotiations relating to their specific support levels, albeit the government is offering both capital expenditure (capex) and operational expenditure (opex) support for selected projects.

Each project will be reviewed based on affordability, value for money and subsidy control considerations, and government funding is expected to support the construction and operational phases of any development. While the specific support for each project will be negotiated directly with the project owner, the following is potentially available: Support for up to 50% of the total capital costs of the project, in addition to further payments based on each tonne of CO_2 captured to cover capex and opex costs for both carbon capture and the associated transportation and storage.

[47] Department for Business, Energy and Industrial Strategy. Carbon Capture, Usage and Storage: Industrial Carbon Capture business models summary. December 2022.

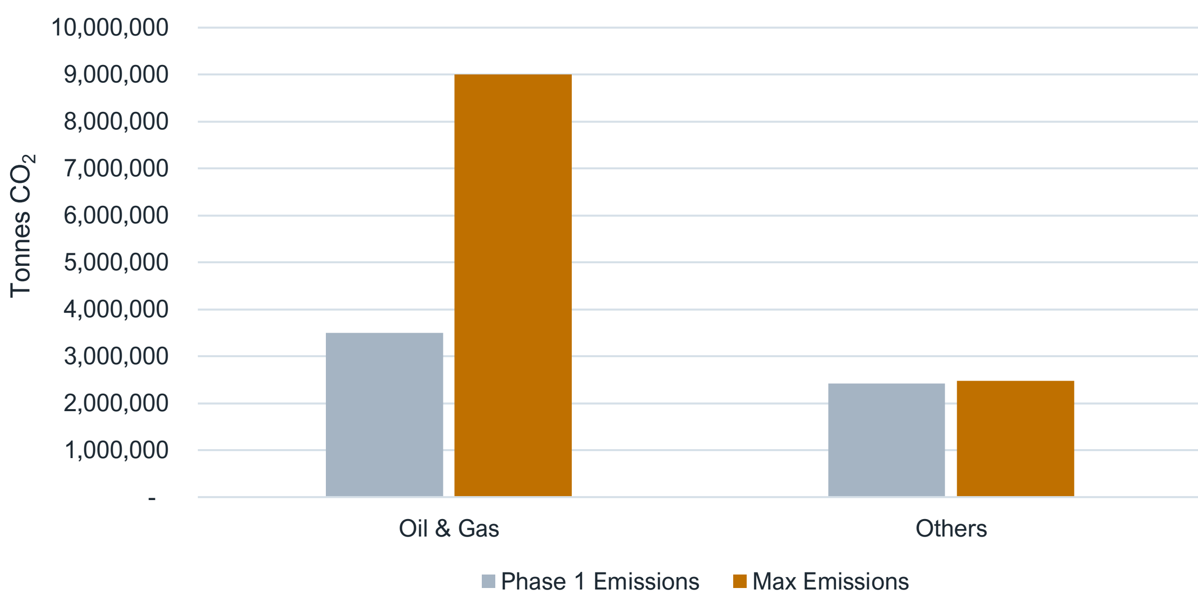
Given the enormous amount of public support on offer, the UK government needs to ensure that CCS projects deliver on their commitments and that funding will only support carbon that has proven to be captured and stored effectively. The technical uncertainties and historical track record from other demonstrator projects globally point to most projects not delivering their stated aims.

Conclusions

As we have noted, the UK government's Track 1 projects are disproportionality supporting blue hydrogen production and significantly under-supporting carbon reduction within electricity supply and greenhouse gas removals, or BECCS. While this may potentially change as the UK government continues bilateral discussions with Track 1 project owners, to date the effectiveness and legitimacy of policy support is at best questionable.

Using our estimates of the volumes of carbon to be captured during the initial phase of the Track 1-supported projects, most of the support is being directed at oil and gas project owners. Oil and gas owner projects will account for around 59% of total emissions during project startup, and assuming further CCS expansion is progressed these projects will represent 78% of carbon capture. This also includes the proposed new-build gas-fired power station, Net Zero Teesside Power, which sees UK-headquartered integrated oil and gas company BP move into the UK fossil power generation market.

Figure 8: Carbon Capture Project Volumes by Project Owner (Tonnes of CO_2)



Source: IEEFA analysis.

It has often been argued that CCS is being used by the fossil fuel industry to justify and support the continued use of fossil fuels within the global energy mix, and UK activity seems to support this. Of the Track 1 projects proposed for support, some 81% of captured emissions are proposed to come from processes that require fossil gas use.

It is concerning that the UK government is being influenced in this way. Previous analysis from IEEFA has highlighted the environmental and cost issues related to blue hydrogen production relative to green hydrogen, or using gas as opposed to renewable power.[48] There are concerns about locking in long-term fossil gas demand when greener, cheaper alternatives with greater security of supply exist.

Additionally, the support of new-build gas power generation is also worrisome. The CCC recognises that the UK will continue to rely on gas power generation as the country progresses to net zero over the coming decades while lower carbon electricity capacity increases. To limit the environmental impact, it is targeting that all gas power generation will be abated by 2035[49] or that existing gas power stations will have CCS retrofitted. It is unlikely that the intention was to support additional gas-fired power stations when simultaneously the UK is rapidly increasing renewable and nuclear power generation capacity.

While we cannot comment on the UK government's decision-making process to initially support such a high proportion of fossil-based CCS, we can make some observations. Firstly, when examining the information available and the progress of proposed CCS projects, it appears that the oil and gas sponsors are better organised and further progressed with their plans. By definition they are highly motivated—continued and long-term commitment to fossil gas use is core to their business model—but they are also well funded, in addition to being experienced and sophisticated lobbyists.

There are also cost and technical factors to take into account. As we have noted previously, the cost of CCS for gas or coal power generation is expensive relative to hydrogen or ammonia production. Additionally, there are no gas-powered CCS projects in existence, increasing the technical risk and viability.

This may be the case for BECCS and why the UK government has not included any projects in the Track 1 portfolio at this point. As the highest-cost CCS solution, this may present a challenge for the UK government, preferring to support projects with a lower cost burden and attempting to limit the risks associated with providing public funds.

[48] IEEFA. Blue hydrogen costs 36% higher than UK's 2021 estimate, would increase gas import dependency. May 2022.
[49] Climate Change Committee. Sixth Carbon Budget. December 2020.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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