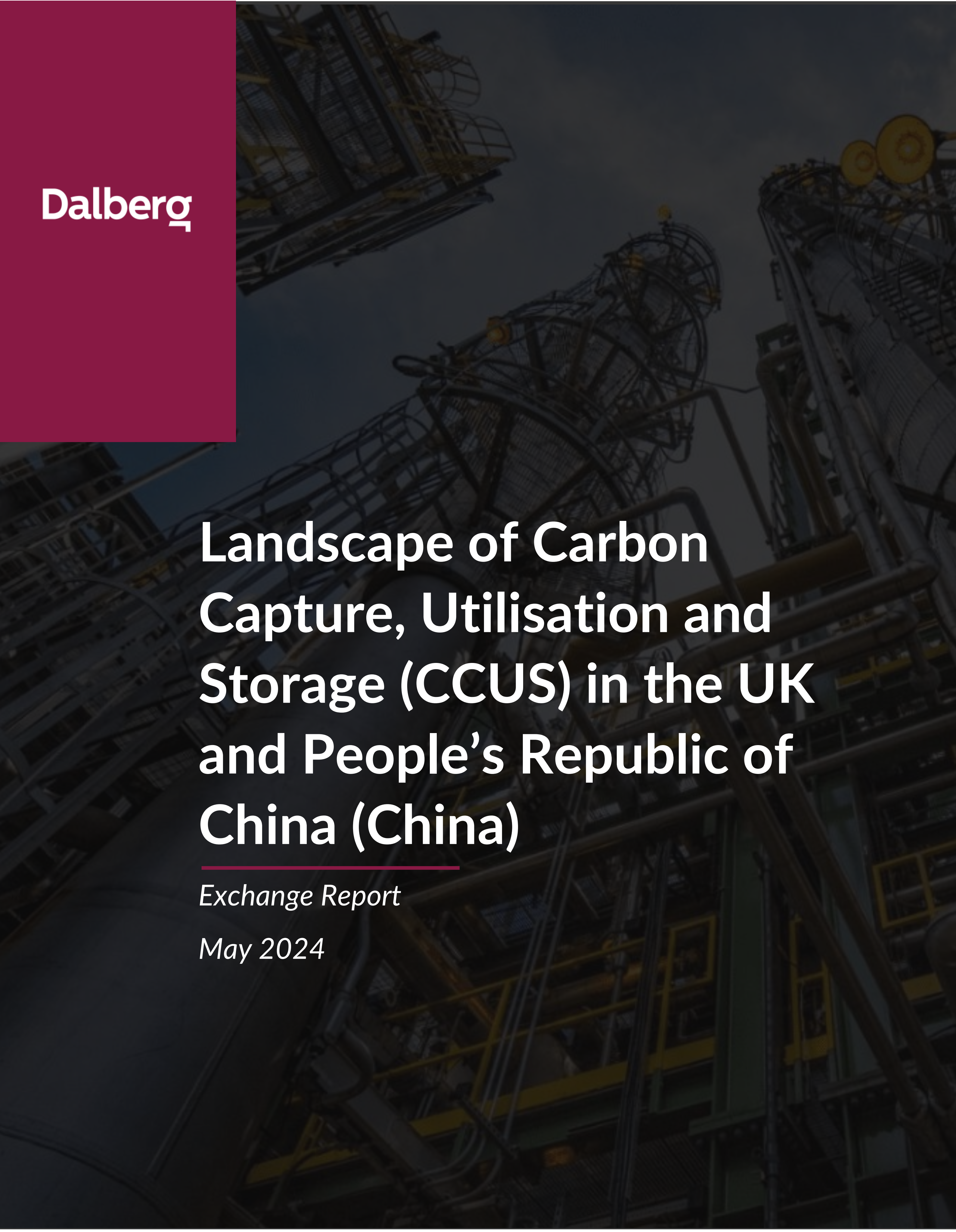

Dalberg

Landscape of Carbon Capture, Utilisation and Storage (CCUS) in the UK and People's Republic of China (China)

Exchange Report

May 2024

Royal Academy of Engineering

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1. UK-China Carbon Capture, Utilisation & Storage Landscape

1.1. The UK and China's policy objectives for CCUS

The UK and China have set ambitious net-zero targets and CCUS is expected to play a key role in achieving these.

The UK's Climate Change Committee declared CCUS a "necessity not an option" to achieve net zero emissions by 2050, with carbon capture offsetting up to 10% of current emissions. In this regard, the country will establish CCUS in two industrial clusters by the mid-2020s and aim for a total of four sites by 2030, with an ambition to capture and store 20-30 megatonnes (Mt) of carbon dioxide (CO_2) each year. This is equivalent to ~7-10% of annual net CO_2 emissions in 2023 or taking 4-6 million cars off the road.[1]

China has also positioned CCUS as one of the most important means of achieving its target of carbon peak by 2030 and carbon neutrality by 2060. In 2019, the government issued an updated Roadmap for Development of CCUS Technology in China which defined its overall vision and several phase-wise goals in five-year increments to 2050. By 2030, China aims for CCUS to be ready for industrial application, and a long-distance onshore pipeline with transportation capacity of up to 2 Mt of CO_2 per annum to be available.[2,3] China also aims to reduce the cost and energy consumption of CO_2 capture by 10-15% by 2030 and 40-50% by 2040. By 2050, CCUS is targeted to be deployed widely, supported by multiple industrial CCUS hubs across the country.[4]

The CCUS ambitions of the two countries can create significant benefits and employment opportunities for their domestic economies. The UK's CCUS Vision is expected to boost its economy by £5 billion a year by 2050 and support 50,000 jobs by 2030.[5] The International Energy Agency (IEA) and the Asian Development Bank (ADB) estimate that CCUS could create additional value of between 0.2-0.6% of China's 2019 GDP by 2030, amounting to ~£80 billion.[6,7] This is also expected to create between 90,000 and 200,000 direct jobs by 2030.[8]

1.2. Funding & policy support for CCUS in the UK and China

The UK is at the forefront of developing policy and funding support for CCUS. China's long-held focus on CCUS has also been strengthened by recent policy developments.[9]

The UK government, in the first phase of its approach, has focused on outlining the framework for CCUS regulation and laying the foundations for a self-sustaining private market. The UK government has a three-phased approach to CCUS development – (i) market creation by 2030, (ii) market transition, and finally (iii) a self-sustaining market by 2050. In the first phase, the government has created a robust legislative framework for the regulation of CCUS via the *Energy Act 2023*.[10] This framework has been designed to address cross-chain risks[11] and encourage the development of CCUS business models that attract private investment.[12] To further improve investor confidence in this highly nascent sector, a "build it and they will come" approach has been adopted, offering financial assistance and guaranteed returns to first movers in industrial CCUS and transportation and storage sectors.[13]

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[1] UK Infrastructure Bank, Strategy Update: Carbon capture, usage, and storage, 2023
[2] Asian Development Bank, Road Map Update for Carbon Capture, Utilization, and Storage Demonstration and Deployment in the People's Republic of China, 2022
[3] IEA, Energy Technology Perspectives: Special Report on Carbon Capture Utilisation and Storage, 2020
[4] Ibid.
[5] UK's Department from Energy Security and Net Zero, Press Release: New vision to create competitive carbon capture market follows unprecedented £20 billion investment, 2023
[6] McKinsey & Company, Unlocking Asia-Pacific's vast carbon capture potential, 2023
[7] This value is converted from US$100 billion as per the exchange rate prevailing on 7th May 2024.
[8] Oil and Gas Climate Initiative, CCUS in China: The value and opportunities for deployment, 2021
[9] The UK has prioritised the development of careful policy even as it lacks operational CCUS projects. In China, while several CCUS projects are in operation, policy gaps remain. Further detail is furnished in upcoming sections.
[10] The Energy Act 2023 sets out the powers and duties given to the Office of Gas and Electricity Markets (Ofgem) as the economic regulator for CO_2 transport and storage (T&S), makes provisions for government fiscal support, allows for new types of T&S economic licenses and allocation processes to be established and gives the Secretary of State the power to designate a CCUS Strategy and Policy statement which will articulate the government's priorities and desired policy outcomes for CCUS.
[11] Cross chain risks arise when the actions or omissions of one part of the value chain have the potential to negative impact other parts.
[12] UK's Department for Energy Security & Net Zero, Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market, 2023
[13] NITI Aayog, Carbon Capture, Utilization and Storage (CCUS): Policy Framework and its Deployment Mechanism in India, 2022

The UK government has significantly stepped-up funding for CCUS, committing £20 billion to support the early deployment of CCUS. Many other net-zero transition funding mechanisms are also available for CCUS. In 2020, the UK government confirmed a £1 billion investment for the deployment of CCUS in four industrial clusters by 2030. In 2023, this was subsumed by a longer-term funding package of £20 billion (mentioned above), to be rolled out over 20 years.[14] CCUS-enabled hydrogen projects can also access capital support through the £240 million Net Zero Hydrogen Fund.[15,16] Between 2004-21, the UK government funnelled over £346 million towards CCUS research and innovation. It has planned for and is currently investing an additional £115 million to support CCUS and Greenhouse Gas Removal technologies under the Net Zero Innovation Portfolio.[17,18] Furthermore, to encourage private investments in sectors like CCUS, the government set up the UK Infrastructure Bank with an initial capital infusion of £12 billion.[19]

In subsequent phases, policymakers in the UK will focus on measures to improve private sector confidence in CCUS. A few examples of developments already underway or being explored include evolving the UK's Emissions Trading Scheme to better align with the net zero trajectory, designing policies that address carbon leakage, a potential Carbon Take Back Obligation or Carbon Storage Obligation for companies that extract fossil fuels, a Carbon Border Adjustment Mechanism for carbon-intensive imports into the UK, among others.[20]

CCUS has long been a focus in China. CCUS had been included in China's national carbon mitigation strategies as far back as the 12th Five-Year Plan (2011-2015).[21] These early-stage policies focused on demonstrations and pilots.[22] With the announcement of China's 30/60 goals and the establishment of the country's "1+N" policy system[23] for emission peaking and carbon neutrality, the Chinese government has increased policy cover for CCUS. As of October 2022, China had issued 70 CCUS-related policies at the national level, including plans, standards, roadmaps, and technology catalogues. These documents lay out proactive plans for future CCUS research and development, investment, and technology cooperation.[24]

The Chinese government has also been expanding the scope of CCUS-related policies, including through an increased number of policies related to technical standards, investment, and financing. For example, CCUS projects were included in the updated *Green Bond Endorsed Projects Catalogue (2021 Edition).* This has the potential to attract further green investments in the country. CCUS has also been mentioned in more sectoral policies including those in hard-to-abate sectors, whereas it was previously only mentioned in power and oil & gas industries. Local governments have also increased their support for CCUS development. As of late 2022, ten subnational governments had deployed CCUS R&D and promotion programs according to local conditions.[25] For e.g., the Guangdong Province has offered incentives for CCUS demonstration projects in the power plant industry.[26]

State-owned enterprises (SOEs) in China have provided most of the funding for CCUS to date.[27,28] Several major SOEs in China have been quick to respond to the central government's carbon neutrality goals with their own plans to advance green technologies, including CCUS.[29] For example, in August 2022, the Sinopec Group

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[14] This amount includes the £1 billion in funding committed earlier.
[15] The Net Zero Hydrogen Fund is a grant fund by the UK government that provides development and capital expenditure to support the commercial deployment of new low carbon hydrogen production projects.
[16] UK Infrastructure Bank, Strategy Update: Carbon capture, usage, and storage, 2023
[17] The Net Zero Innovation Portfolio is a £1 billion packet of competitive funding schemes by the UK government to accelerate the commercialisation of low carbon technologies, systems, and business models in power, buildings and industry.
[18] UK's HM Government, Hydrogen Net Zero Investment Roadmap, 2024
[19] UK's HM Treasury, UK Infrastructure Bank Policy Design, 2021
[20] UK's Department for Energy Security & Net Zero, Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market, 2023
[21] IEA, Energy Technology Perspectives: Special Report on Carbon Capture Utilisation and Storage, 2020
[22] Global CCS Institute, Repositioning CCUS for China's Net-Zero Future, 2022
[23] China's "1+N" policy framework consists of overarching guidance: the "1", and action plans and policy measures for key sectors and industries: the "N". These policies prioritise the decarbonisation of the industrial sector, primarily focusing on building materials, metallurgy, and chemical industries.
[24] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[25] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[26] Jiutian, Z., Zhiyong, W., Jia-Ning, K. *et al.*, Several key issues for CCUS development in China targeting carbon neutrality, 2022
[27] Insights from UK-China Bilateral Exchange on CCUS
[28] Total amount spent by Chinese State-owned Enterprises on CCUS projects is unknown.
[29] Zhang Fang and Zuo Jialu, State-Owned Enterprises' Responses to China's Carbon Neutrality Goals and Implications for Foreign Investors, 2023

launched China's first 1 Mt per annum-scale CCUS project in a coal gasification unit.[30] Other SOEs like the China National Petroleum Corporation (CNPC) and the China National Offshore Oil Corporation (CNOOC) are also building several large-scale CCUS demonstration projects. A few include a cluster in Xinjiang which is expected to reach a capacity of 10 Mt CO_2 per year by 2030 and China's first offshore storage project in the Pearl River Mouth Basin expected to store more than 300,000 tonnes of CO_2 per year.[31,32] The Chinese national and provincial governments have contributed roughly £110 million[33] towards CCUS development to date, largely focused on research and innovation.[34] The People's Bank of China, the country's central bank, has also made ~£32.5 billion[35] in concessional finance available to Chinese financial institutions to incentivise re-lending for green projects. This Carbon Emission Reduction Facility had led to ~£65 billion[36] in re-lending to such projects by the end of 2022 and helped reduce carbon emissions by 100 Mt in that year.[37] The proportion of this allocable to CCUS is unclear.

1.3. Current CCUS projects in the UK and China

Similar to the state of CCUS globally, most existing projects are at the pilot or demonstration stage however, both the UK and China have a strong pipeline of large-scale projects.

The UK government has aimed to support the development of CCUS projects in 4 industrial clusters by 2030. Several projects commercially capture CO_2 in the UK however no full chain projects (from capture to storage) have been put into operation yet.[38,39] In 2021, the government launched the CCUS cluster sequencing process, structured in two tracks. In 2023, negotiations commenced with eight capture projects in two Track 1 clusters (HyNet and the East Coast Cluster) set to enter operations by mid-2020s.[40] In the same year two additional clusters (Acorn and Viking) were selected for Track-2 development due to launch by 2030.[41] The response from industry has also been positive. The number of planned projects in the wider UK pipeline have grown, with enough schemes to capture 94 Mt of CO_2 per year.[42,43] Government-supported cluster projects continue to edge closer to operation despite delays due to slow decision making on outlining business-model blueprints, long permitting processes, and rising costs[44,45,46].

China has several CCUS projects in operation already and the scale of projects has been increasing. As of late 2022, there were around 100 CCUS demonstration projects either in operation or planning in China. Almost half of these had been put into operation with a capture capacity of more than 6 Mt per year.[47,48] At present, these are largely point-to-point projects[49] in the pilot or demonstration phase, are implemented by state-owned enterprises and use trucks for transportation.[50] In recent years, the scale of projects in operation or under

[30] Insights from UK-China Bilateral Exchange on CCUS
[31] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[32] The State Council of the People's Republic of China, China's first offshore CO_2 storage well begins drilling, 2023
[33] Converted from RMB 1 billion using exchange rate prevailing on 28th May 2024
[34] Insights from UK-China Bilateral Exchange on CCUS
[35] Converted from RMB 300 billion as per exchange rate prevailing on 28th May 2024
[36] Converted from RMB 600 billion as per exchange rate prevailing on 28th May 2024
[37] Central Banking, PBoC has lent banks $44 billion for 'green projects', 2023
[38] Insights from the UK-China Bilateral Exchange on CCUS
[39] This is excluding biochar or Enhanced Weathering projects which store an unverified amount of CO_2 per year.
[40] Track-1 was split into two sequential phases: Phase 1 to select the two priority clusters and Phase 2 to shortlist emitter projects.
[41] UK's Department for Energy Security & Net Zero, Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market, 2023
[42] The Carbon Capture and Storage Association, CCUS Delivery Plan Update, 2023
[43] In 2022 the 'CCUS Delivery Plan 2035' highlighted the need for additional storage to accommodate the capture project pipeline. In response to this the UK offered 21 carbon storage licenses in 2023 which had all been accepted. Pending some clarity on the commercial structures under which these storage sites will operate, licensed storage volumes could sufficiently accommodate the current capture project pipeline out to 2050.
[44] Upstream, Final investment decisions in doubt: UK government go-slow hurting CCS dreams, 2023
[45] Upstream, Industry warms UK to strengthen carbon capture commitments or see lead fade away, 2023
[46] Energy Voice, UK considers delaying some carbon capture projects as costs soar, 2024
[47] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[48] UK-China (Guangdong) CCUS Centre, UKCCS, The Administrative Center for China's Agenda 21, Carbon Capture, Usage & Storage (CCUS) Supply Chain Cooperation: Unlocking the full potential of CCUS for the UK and China, 2024
[49] Point-to-point projects typically focused on the emissions of a single emitter where CCUS hub and cluster networks brings together multiple carbon dioxide (CO_2) emitters and/or multiple storage locations using shared transportation infrastructure.
[50] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023

construction has been increasing. The number of projects with a capacity of 100 kilotonnes (kt) has reached more than 40 and among these more than 10 have a capacity of 500 kt CO_2.[51] Between 2022 and 2023, China's first Mt per annum-scale CCUS project and first commercial-scale CO_2 transport pipeline with a length of 109 km were put into operation.[52]

China also has clear plans for larger projects, and projects under development are covering an increasing range of sectors. Several large-scale demonstration projects are under development in China including one cluster in Xinjiang which is expected to reach an annual capacity of 10 Mt CO_2 by 2030.[53,54] Two other 10 Mt-scale projects are being studied – one in the Daya Bay area and another in East China.[55] Moreover, projects are being demonstrated in a vast variety of sectors with those in hard-to-abate sectors increasing significantly from 2021 to 2022.[56]

1.4. Primary assets of the UK and China for CCUS

Both countries have distinct strengths in the CCUS domain, and they stand to benefit significantly from collaborating with each other.

The UK is well positioned to develop CCUS due to its early policy efforts, strong R&D and select supply chain capabilities, and robust capital markets. The UK is an early mover in the development of complex and interconnected regional decarbonisation hubs and at the forefront of developing policy frameworks and business models for CCUS.[57,58] UK's ambitions are supported by its capacity to safely store 78 billion tonnes of CO_2 under the seabed – one of the largest such capacities in the world.[59] The country is a source of several cutting-edge CCUS innovations.[60] Industry in the UK also holds key capabilities in engineering consultancy, project development, financing expertise and manufacturing of key components such as heat exchangers, column internals and filters.[61] Moreover, London is home to Europe's largest capital market with a deep pool of liquidity and international investors (including from China), laying a strong foundation to capitalise on financing opportunities for planned CCUS clusters.[62,63]

China's market scale, cost advantages, and robust domestic supply chains create a favourable environment to scale CCUS rapidly. The technology can leverage unmatched economies of scale in China due to the immense volume of industrial cluster developments across the country. This can lead to significant cost reductions.[64] In fact, China already has certain cost advantages. Given the sizable number of CCUS projects already underway in China, costs have been falling year on year as the local industry climbs the learning curve. Overall, CCUS costs in China have the potential to be 10-30% lower than in advanced economies like the UK.[65] This is due to efficient equipment manufacturing, transportation, and access to cost-effective materials.[66] This large canvas in China presents an opportunity to embrace early lessons from major projects around the world.[67] China's comparative advantage in manufacturing, availability of required skill sets within the country, and a strong

[51] Ibid.
[52] Global CCS Institute, China Continues to Advance CCUS in 2023, 2023
[53] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[54] CNPC is setting up China's first CCUS hub in the Xinjiang Junggar Basin. In the first phase, 1.5 Mt of CO_2 per year will be captured from one of CNPC's own refineries. In the second phase, the project will capture CO_2 from nearby coal-fired power plants, steel mills, cement plants and other high-emission industries, while expanding its transport system. Initially, this CO_2 will be used for Enhanced Oil Recovery, but the plan is to move towards long term geological storage.
[55] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[56] Ibid.
[57] Insights from the UK-China Bilateral Exchange on CCUS
[58] Department for Energy Security and Net Zero, A Remarkable New Infrastructure System: Opportunities for economic growth in the UK's Carbon Capture & Storage Industry, 2023
[59] UK's Department of Energy Security and Net Zero, Carbon Capture, Usage and Storage: A Vision to Establish a Competitive Market, 2023
[60] Insights from UK-China Bilateral Exchange on CCUS
[61] UK-China (Guangdong) CCUS Centre, UKCCS, The Administrative Center for China's Agenda 21, Carbon Capture, Usage & Storage (CCUS) Supply Chain Cooperation: Unlocking the full potential of CCUS for the UK and China, 2024
[62] China-Britain Business Council, KPMG, Targeting Net Zero: The Role of UK-China Business, 2021
[63] Insights from the UK-China Bilateral Exchange on CCUS
[64] China-Britain Business Council, KPMG, Targeting Net Zero: The Role of UK-China Business, 2021
[65] UK-China (Guangdong) CCUS Centre, UKCCS, The Administrative Center for China's Agenda 21, Carbon Capture, Usage & Storage (CCUS) Supply Chain Cooperation: Unlocking the full potential of CCUS for the UK and China, 2024
[66] Ibid.
[67] China-Britain Business Council, KPMG, Targeting Net Zero: The Role of UK-China Business, 2021

logistics sector create a complete domestic supply chain which can enable rapid development of CCUS projects and resilience from external shocks.[68,69]

1.5. Key roadblocks to scaling CCUS in the UK and China

Despite their strengths, the growth of CCUS is hindered in both countries by several common roadblocks.

High capex and opex costs in the face of low carbon prices and unproven business models: In the UK, CCUS deployment costs have more than doubled since 2020 due to inflation and are expected to increase further.[70] Even in China, the cost of CO_2 capture is high in sectors like cement and coal-fired power[71] due to low concentrations of CO_2 in the flue gas and presence of impurities which demand the use of more cost-intensive technologies.[72] Cement plants in China are mainly small and geographically dispersed, also increasing cost.[73] In both countries, a lack of design standardisation adds to upfront cost and the high risk associated with projects drives up the cost of capital.[74] At the same time China's ETS is yet to cover emission reductions from CCUS[75] and the price of carbon on UK's ETS had slumped to an all-time low towards the end of January 2024.[76] Most other business cases for CCUS today rely on specific policy enablement (e.g., subsidies, revenue support packages etc.). Non-subsidy revenues which are critical to scaling the sector are still immature potentially leading to hesitation in committing commercial capital.[77]

Need for significant multi-sectoral collaboration and managing of risks across stakeholders: Developing integrated CCUS projects requires collaboration across multiple stakeholders (emitters, transport operators, storage sites etc.) along a complex value chain. The need for complicated commercial agreements has reduced the appeal of such projects in China in the past.[78] Moreover, members of the value chain are exposed to significant cross-chain risks[79] which have been cited as a major reason for the failure of historical attempts to develop large-scale CCUS projects in the UK.[80,81]

Technologies required for scale-up are still in early stages: Around three quarters of capture capacity envisioned by 2050 in the International Energy Agency's Net Zero Roadmap relies on technologies and applications that are still in the demonstration or prototype stage.[82] These include carbon removal, new ways of utilising captured CO_2 (particularly to make fuels and chemicals), carbon capture in cement and iron & steel production, among others.[83] The UK has a comparative advantage in CCUS innovation but the business case for investing may depend on the pace of developing commensurate skills and supply chains, which are essential to retain economic value.[84]

Geological and engineering challenges increase the cost and risk associated with storage projects: Realistic CO_2 storage potential in the UK and China is expected to be lower than theoretically predicted.[85] For example, 1 in 10 boreholes in the UK cannot be sealed properly and hence are not fit for storing CO_2.[86] In the UK, research is in progress to meet high standards of borehole sealing.[87] Moreover, major emission sources in the Eastern region of China and the South Wales or Southampton clusters in the UK lack proximate sites for CO_2 storage, requiring more costly transport solutions by train, pipelines and river borne or coastal shipping (which

[68] London School of Economics, Seizing sustainable growth opportunities from carbon capture, usage and storage in the UK, 2021
[69] Insights from UK-China Bilateral Exchange on CCUS
[70] Carbon Tracker, Curb your Enthusiasm: Bridging the gap between the UK's CCUS targets and reality, 2024
[71] The Administrative Center for China's Agenda 21, Global CCS Institute, Tsinghua University, CCUS Progress in China – A Status Report, 2023
[72] Insights from the UK-China Bilateral Exchange on CCUS
[73] Ibid.
[74] Ibid.
[75] Ibid.
[76] Carbon Tracker, Curb your Enthusiasm: Bridging the gap between the UK's CCUS targets and reality, 2024
[77] McKinsey and Company, Scaling the CCUS industry to achieve net-zero emissions, 2022
[78] Global CCS Institute, Repositioning CCUS for China's Net-Zero Future, 2022
[79] Cross chain risks arise when the actions or omissions of one part of the value chain have the potential to negative impact other parts.
[80] Clean Air Taskforce, Risk Allocation and Regulation for CO_2 Infrastructure, 2024
[81] Cross chain risks arise when the actions or omissions of one part of the value chain have the potential to negative impact other parts.
[82] IEA, New policy and business approaches are needed to support scaling up of CCUS to reach net zero goals, 2023
[83] IEA, Energy Technology Perspectives: Special Report on Carbon Capture Utilisation and Storage, 2020
[84] London School of Economics, Seizing sustainable growth opportunities from carbon capture, usage and storage in the UK, 2021
[85] Insights from the UK-China Bilateral Exchange on CCUS
[86] Ibid.
[87] Insights from the UK-China Bilateral Exchange on CCUS

are being developed in the UK and Europe).[88,89] Quantifying storage also requires the compilation of an evidence-based, rigorous geographical catalogue of potential storage resources.[90] Due to the lack of geological survey technology in China companies lack detailed geological information before the project is carried out, making it difficult to accurately assess project risk.[91]

Both countries are also facing unique challenges owing to their specific characteristics:

Worker and skill shortages have been identified as challenges that could potentially impede the timely delivery of CCUS projects in the UK. Transitory peaks in job creation in the UK construction sector from CCUS projects could overlap with peaks from other decarbonisation areas which might need to be implemented over similar timeframes.[92] These peaks are temporary, and shortages could be mitigated with careful planning, worker migration from the offshore oil and gas sector etc. Adding to the challenge, the engineering construction industry will need to replace or re-train an aging and non-diverse workforce, implying the need to attract a large number of new and re-skilled personnel into extensive training programs in a sector that suffers from low public awareness.[93] In engineering construction alone, ~40% of the UK's workforce is over the age of 50, and only 5% under the age of 25. Similar challenges are expected to persist with trainers.[94] In one survey of UK energy professionals, 50% of those expecting a switch to the CCUS field cited barriers to their professional development such as lack of appropriate training.[95]

Lack of incentive policies and regulatory frameworks for CCUS in China lead to uncertainties around long-term sustainability of projects. At present, costs for CCUS projects are absorbed by companies (largely state-owned) due to a lack of subsidy and incentive policies.[96] High operating and maintenance costs also increase financial strain on enterprises.[97] The lack of an overarching regulatory framework also leads to limited legal protection and increased risk for companies carrying out such projects.[98] This might hinder the long-term commercialisation potential of CCUS in China.[99]

1.6. Existing CCUS collaborations between the UK and China

Greater coordination at the political level has led to longstanding, fruitful collaborations between businesses and researchers in the UK and China towards net-zero transitions.

The UK and China have been collaborating with each other on climate action more broadly since over a decade. The UK-China joint statement on climate change released in 2014 is among the most ambitious bilateral documents in the area. In 2015, both governments signed an agreement for a Clean Energy Partnership to support each other during their transitions to low carbon economies. The UK-China Green Financing Taskforce, established by the City of London Corporation and the China Green Finance Committee has served as a key platform for green finance collaboration since 2016. More recent government level meetings between the two countries have reiterated a commitment to enhance cooperation on key green technologies.[100]

Notably, the China-UK Near Zero Emissions Coal (NZEC) Initiative, the UK-China (Guangdong) CCUS Centre and the Sino-British Engineering Technology Cooperation represent key milestones in bilateral collaboration. The China-UK NZEC Initiative was developed in 2005 to support the broader EU-China NZEC Agreement and examined the merits of various options for carbon capture, transport, and geological storage in China.[101,102]

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[88] Wang, P., Shi, B., Li, N. et al., CCUS development in China and forecast its contribution to emission reduction, 2023
[89] Insights from the UK-China Bilateral Exchange on CCUS
[90] Ibid.
[91] Sun Y, Li Y, Zhang F, Liu C., Obstacle Identification and Analysis to the Commercialization of CCUS Technology in China under the Carbon Neutrality Target, 2022
[92] IDRIC, Policy brief: Understanding jobs demand and displacement outcomes of decarbonising UK industry clusters, 2024
[93] The Carbon Capture and Storage Association, CCSA Workforce & Skills Position Paper, 2023
[94] Ibid.
[95] Energy Barometer, The net zero skills issue: Bridging the gap to a low carbon workforce, 2021
[96] Insights from the UK-China Bilateral Exchange on CCUS
[97] Sun Y, Li Y, Zhang F, Liu C., Obstacle Identification and Analysis to the Commercialization of CCUS Technology in China under the Carbon Neutrality Target, 2022
[98] Ibid.
[99] Ibid
[100] China-Britain Business Council, KPMG, Targeting Net Zero: The Role of UK-China Business, 2021
[101] This was supported by up to £3.5 million from the UK's Department on Energy and Climate Change in partnership with the Chinese Ministry of Science and Technology (MOST).
[102] NZEC, China-UK Near Zero Emissions Coal (NZEC) Initiative Summary Report, 2009

Under the initiative collaborative research activities were undertaken by Chinese and UK experts from ~30 organisations.[103] Further collaboration is championed by the UK-China (Guangdong) CCUS Centre, established in 2013. The centre is a hub for research and engineering activities, including development of CCUS demonstration projects in South China. It is supported by a variety of players across government, industry and academia from both the UK and China.[104] This spirit of collaboration has sustained over the years. In 2022, the Royal Academy of Engineering and the Chinese Academy of Engineering launched the Sino-British Engineering Technology Cooperation to promote partnership among the engineering communities of both countries on the topic of decarbonisation, with a focus on offshore wind technology and CCUS in the near term.[105,106]

China's green light for foreign investments in CCUS and close ties of UK companies in China's CCUS sector also highlight strong industrial collaboration. In 2022, China issued the Catalogue of Industries for Encouraging Private Investment, which calls for foreign investment in a number of CCUS-related fields. Prominent UK companies like Shell, bp, Howden, and Wood play significant roles in China's CCUS sector. These companies directly collaborate with Chinese enterprises to develop projects, supply key inputs, provide research and strategic expertise etc. Shell, in particular, is a major player with several collaborations across regions for example, through a partnership with Sinopec, Baowu Steel, and BASF to explore an open-source CCUS cluster in Shanghai and Jiangsu. Several other UK companies are also linked to China's CCUS sector or have expressed an interest in exploring such opportunities.[107]

[103] Ibid.
[104] SCCS, Renewed Memorandum of Understanding to mark 10th anniversary of the UK-China (Guangdong) CCUS Centre, 2024
[105] Chinese Academy of Engineering, Steering Committee on Sino-British Engineering Technology Cooperation inaugurated, 2022
[106] Chinese Academy of Engineering, Steering Committee on Sino-British Engineering Technology Cooperation holds annual meeting, 2023
[107] UK-China (Guangdong) CCUS Centre, UKCCS, The Administrative Center for China's Agenda 21, Carbon Capture, Usage & Storage (CCUS) Supply Chain Cooperation: Unlocking the full potential of CCUS for the UK and China, 2024

2. ANNEX

2.1. Details of the exchange

Agenda: UK-China Bilateral Exchange on CCUS, 20 May – 24 May 2024, China

Day 1: Monday 20th May 2024 | *One-day seminar event*

- **Bilateral Exchange on CCUS:** This one-day seminar was hosted by the Royal Academy of Engineering in collaboration with the Chinese Academy of Engineering at the Beijing University of Chemical Technology. The event hosted several sessions and speakers:
    - Introduction to the overall situation of net-zero emissions in China and the UK by Professor Jianfeng Chen and Professor Martin Blunt
    - Large-scale and low-cost carbon capture and utilisation by Professor Jianfeng Chen
    - Overview of the extent and growth of CCS physical processes in storage and use in enhanced oil recovery by Professor Martin Blunt
    - Development of CCUS in China by Professor Yang Li
    - R&D in CCUS, industry landscape and barriers to innovation by Dr. Charalampos Michalakakis
    - CCUS technologies and industrial decarbonisation, role of clusters anchoring CCUS projects by Professor Mercedes Maroto-Valer
    - Chemical-biological coupled catalysis for carbon fixation synthesis of fuels and chemicals by Professor Tianwei Tan
    - Carbon storage, methods, pace and payment by Professor Stuart Haszeldine
    - Prospect of biochar-based net-zero emission technology by Professor Wenfu Chen
    - Tasks and challenges of building energy transformation by Professor Yi. Jiang
    - Advanced carbon capture for steel industries integrated in CCUS clusters by Professor Haroun Mahgerefteh
    - The green transformation path of architecture under the drive of materials innovation by Professor Shou Peng
    - Decarbonising the cement and steel industries: CCUS in China's cement and steel sectors by Professor Xi Liang

Day 2: Tuesday 21 May 2024 | *Site visits*

- **Site visit to the Qilu Petrochemical-Shengli Oilfield CCUS project:** The UK delegates visited China's first 1 Mt per annum-scale CCUS project in Zibo. Here, CO_2 is captured from tail gas produced in the process of coal-gasification and transported via a 109 km pipeline to the Shengli oilfield for flooding and storage (see below). The visit was preceded by a technical seminar where representatives introduced the project to the UK delegates and addressed their questions regarding the technologies deployed.

Day 3: Wednesday 22 May 2024 | *Site visits*

- **Site visit to Shengli Oilfield's CO_2 Oil Displacement and Storage Demonstration Area:** The UK delegates visited the Shengli Oilfield in Dongying, an important oil industrial base mainly engaged in the exploration and development of oil and gas, the technical service of petroleum engineering, the construction of ground engineering, oil and gas deep processing, and mining service and coordination. Captured CO_2 from the Qilu Petrochemical CCUS project is transported to the Shengli oilfield for enhanced oil recovery.
- **Site visit to the CCUS Laboratory of the Exploration and Development Research Institute.** The UK delegates visited a CCUS lab which is responsible for long-term oil and gas exploration and development, basic research, theoretical and technical research and application, well deployment reserve evaluation, production capacity construction program etc. It is the sole comprehensive geological research institution integrating exploration and development in the Shengli oilfield and is also the key research institute of the Sinopec Group.

Day 4: Tuesday 23 May 2024 | *Transit*

Day 5: Friday 24 May 2024 | *One-day workshop*

- **UK-China workshop on Carbon Capture Utilisation and Storage R&D Collaboration Opportunities:** This one-day workshop hosted by the UK-China (Guangdong) CCUS Centre, China Energy Engineering Group Guangdong Electric Power Design Institute and the British Consulate-General in Guangzhou presented the UK delegates with an opportunity to further hear from experts on CCUS in China. Sessions included:
    - Welcome speeches by Mr Xia Qifeng, Ms Sarah Mann, Mr Peng Xueping, and Dr Karl McAlinden
    - An introduction to CCUS activities in Guangdong and the UK-China (Guangdong) CCUS Centre by Professor Liang Xi
    - Cutting-edge technological innovation with geological and engineering applications in CCUS by Professor Martin Blunt, Professor Peng Pingan, Professor Stuart Haszeldine, Professor Gu Sai, Professor Haroun Mahgerefteh, and Professor Mercedes Maroto-Valer
    - CCUS technological innovation and engineering applications by Dr Charalampos Michalakakis, Dr Xia Changyou, Mr Sun Zhangwei, Fang Xiaoyu, Dr Li Pengchun, and Dr Li Yixi,
    - Closing speech by Mr Zhu Guangtao

2.2. List of attendees

Delegates from the UK:

Professor Martin Blunt, Professor, Imperial College London

Ms Carys Blunt, Finance and Centre Manager, UK Carbon Capture and Storage Research Centre

Dr Kyra Sedransk Campbell, Research Fellow, University of Sheffield

Professor Sai Gu, Deputy Pro-Vice Chancellor, University of Warwick

Professor Stuart Haszeldine, Professor of Carbon Capture and Storage, University of Edinburgh

Professor Xi Liang, Professor, University College London

Professor Haroun Mahgerefteh, Professor, University College London

Professor Mercedes Maroto-Valer, Deputy Principal, Heriot-Watt University; Director, Research Centre for Carbon Solutions

Dr Charalampos Michalakakis, Lead Energy Technical Advisor, Department for Energy Security and Net Zero

Ms Claudia Hernandez Narciso, Process Engineer, CCS UK Industry Expert

Ms Esin Serin, Policy Fellow, London School of Economics

Other attendees from the UK

Ms Sarah Mann, HM Consul General Guangzhou

Dr Karl McAlinden, Consul Commercial of BCG, Head of Energy in China

Mr Reef Erdogan, Head of Innovation, British Consulate Guangzhou

Delegates from China:

Professor Jianfeng Chen, Member and Secretary-General of the Chinese Academy, Chinese Academy of Engineering

Professor Tianwei Tan, Member, Chinese Academy of Engineering; President, Beijing University of Chemical Technology

Professor Yang Li, Member, Chinese Academy of Engineering; Chairman, China Petrochemical Science and Technology Association

Professor Wenfu Chen, Member, Chinese Academy of Engineering; Professor, Shenyang Agricultural University

Professor Jun Meng, Professor, Shenyang Agricultural University; Director, National Biochar Research Institute at Shenyang Agricultural University

Professor Yi Jiang, Member, Chinese Academy of Engineering; Professor, Tsinghua University

Professor Xuwen Xiao, Member, Chinese Academy of Engineering; Chief Expert, China State Construction Engineering Corporation

Mr Xia Qifeng, Deputy Director-General, Guangdong Provincial Department of Science and Technology

Mr Peng Xueping, General Manager, GEDI

Professor Pend Pingan, Academician, Chinese Academy of Sciences; Researcher, Guangzhou Institute of Geochemistry

Dr Xia Changyou, Project Director, GDCCUS

Mr Sun Zhangwei, Director, CCUS Technology Center; Deputy Director, Mechanical and Environmental Protection Department at GEDI

Fang Xiaoyu, Director, Marine green Energy Research Centre

Dr Li Pengchun, Researcher, South China Sea Institute of Oceanology, CAS

Dr Li Yixi, Doctoral Researcher

Mr Zhu Guangtao, Deputy Chief Engineer, GEDI