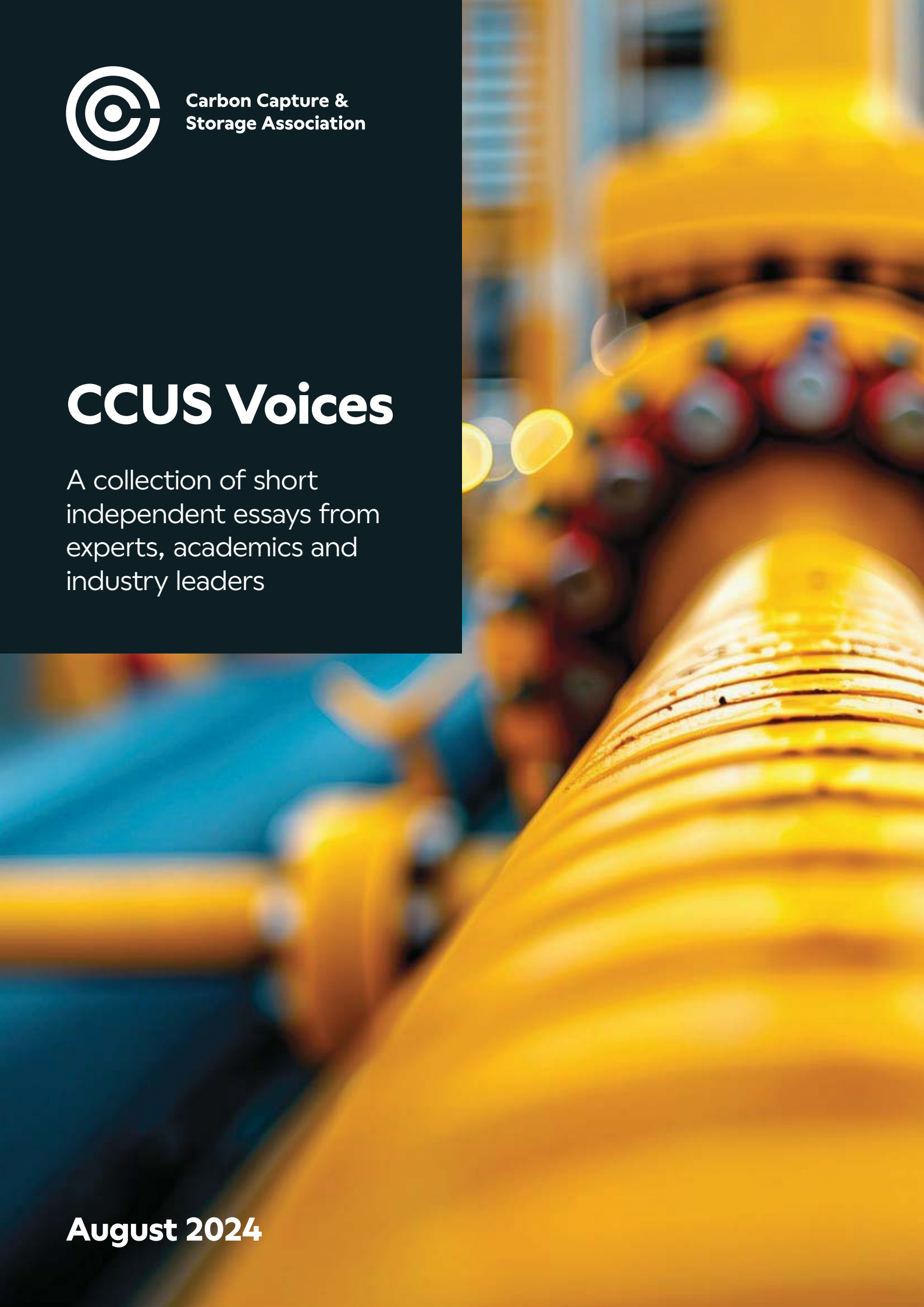
Carbon Capture & Storage Association

CCUS Voices

A collection of short independent essays from experts, academics and industry leaders



August 2024

Expert Opinions and Acknowledgments

We asked these experts to talk about the vital role of Carbon Capture, Utilisation, and Storage (CCUS) in achieving net zero emissions, as well as the challenges facing the industry and the wider benefits of deployment.

The views expressed by the experts are entirely their own and do not reflect the views of the CCSA or its members.

The CCSA extends its gratitude to the contributors for their time and valuable insights that form the basis of this report.

Foreword

The Carbon Capture and Storage Association (CCSA) is the lead trade association accelerating the commercial deployment of Carbon Capture, Utilisation and Storage (CCUS) across the UK and Europe, representing over 120 companies invested in the entire CCUS value chain.

Olivia Powis
UK Director
CCSA

The world is watching the progress in the UK on deploying CCUS, and the CCSA has been encouraged by the pace of decision-making by the new Government.

Establishing the 'Mission Control for Clean Power by 2030' and launching the National Wealth Fund demonstrates the UK Government's understanding of the urgency of delivering net zero at pace.

Critical to decarbonising British industry are the CCUS clusters. The sector holds immense potential for bolstering economic prosperity and fostering job creation. It is projected to deliver up to 70,000 new highly skilled jobs and retain approximately 77,000 existing jobs in critical industries like cement, chemicals and manufacturing across the UK.

The CCUS industry is investing significant sums in the development of the UK's Cluster Sequencing Process and the Government has an exciting opportunity to establish the world's first leading large-scale integrated CCUS clusters.

Over the past three years, the CCSA and our members have been providing the Government with expert knowledge on the development of the CCUS value chain - carbon capture, transport, storage, and utilisation. The CCUS Voices publication brings together insights from industry leaders, academics and experts from across the CCSA membership and beyond, to underscore the pivotal role of CCUS in the UK and EU's transition to a low carbon economy and the associated economic benefits.

These 'Voices' collectively highlight the multiple opportunities, and some of the challenges, within the CCUS landscape, both across the UK and the EU. They stress the need to future-proof key manufacturing and industrial sectors by using CCUS technology. They also highlight the importance of having skilled engineers, supporting women in the industry, building strong carbon dioxide (CO_2) transport infrastructure and cross-border collaboration, and innovating within the supply chain.

The Voices also discuss the potential of Greenhouse Gas Removal (GGR) technologies such as Direct Air Capture with Storage (DACS).

The UK holds a strategic advantage in the CO_2 storage market, capitalising on geological strengths with an estimated CO_2 storage potential of approximately one-third of Europe's total capacity, alongside a wealth of skills and experience in offshore technologies and engineering.

To meet the Climate Change Committee's (CCC) target of 20-30 million tonnes (Mt) of CO_2 captured and stored by 2030, rising to 50-60 Mt by 2035, the UK needs to deploy CCUS at scale and utilise our storage capabilities. Encouragingly, the industry stands ready to deliver CCUS across the UK and EU at pace, as highlighted by the CCUS Voices.

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With Great Power, Comes Great Responsibility: RWE's Role in Decarbonising UK Power Generation

Tom Glover
Chair, CCSA
UK Country Chair, RWE

RWE

"As Chair of the CCSA and RWE's UK Country Chair, I am excited to be part of the UK's CCS journey and see the role it will play in shoring up vital energy security and resilience, whilst driving a global transition to a sustainable future."

RWE is dedicated to ensuring the UK's energy needs are met with firm, flexible, and decarbonised electricity. As the UK's largest operator of gas-fired power stations, alongside a substantial renewables fleet, we're poised to significantly contribute to the nation's energy mix for years to come.

Acknowledging RWE's pivotal role in decarbonising the UK power sector, and as UK Country Chair, I recognise our responsibility. We're committed to transitioning our UK gas fleet to support the UK's decarbonisation targets whilst maintaining security of supply.

Today, gas-fired power stations play an essential role in the UK's energy resilience. However, as we head towards net zero, both Carbon Capture and Storage (CCS) and hydrogen combustion will be critical to decarbonising power stations around the UK.

There is broad consensus, including by the independent Climate Change Committee (CCC), that our electricity system in 2035 will need significant volumes of fossil gas coupled with CCS, whether in post-combustion power plants or as 'blue' hydrogen production to supply hydrogen ready gas turbines.

The CCC also forecasts a requirement for approximately 12 Gigawatts (GW) of unabated gas by 2035, providing around 2% of the UK's electricity supply. To offset emissions from unabated gas generation, negative CO_2 emissions via Bioenergy with Carbon Capture and Storage (BECCS) will also therefore be essential.

In my role as Chair of the CCSA, it's abundantly clear to me the critical role CCS will play in shoring up firm, flexible and decarbonised power generation.

RWE plans to actively contribute to this transition. We are exploring retrofitting CCS at three of our existing power stations (Pembroke, Staythorpe and Great Yarmouth), as well as developing a new 900 Megawatts (MW) CCS-enabled gas plant at Stallingborough. Together, these would enable approximately 5.1GW of secure, flexible, low-carbon energy – enough to power around 8.1 million homes.

Our target is for the first of our fleet to be converted to decarbonised operation by 2030. But it's clear from where I sit, that this ambitious timeline will require significant investment, robust policy support, and major infrastructure development.

For new emitters not already confirmed as part of the Cluster Sequencing Process, we need a clearer view of future cluster expansion. Generators like RWE especially need clarity on the ambition for Power CCS if the UK is to decarbonise power generation by 2035.

For dispersed generation sites, like our Pembroke plant (one of the largest and most efficient in Europe), it's critical we get carbon shipping right. I am pleased Track-2 stores must demonstrate their potential to receive and store CO_2 via shipping.

RWE and the CCSA will continue to engage closely with the Department for Energy Security & Net Zero (DESNZ) as they consult on the policy and commercial delivery of non-pipeline transportation. It's paramount we get this right to ensure emitters aren't left behind, and we can unlock CCS as a global export opportunity.

As Chair of the CCSA and RWE's UK Country Chair, I am excited to be part of the UK's CCS journey and see the role it will play in shoring up vital energy security and resilience, whilst driving a global transition to a sustainable future.

Empowering the Future: The Role of Carbon Capture in the Journey to a Sustainable Economy

Dr. Christie Hazell-Marshall
Associate Technical Partner
ERM

> **"Achieving net zero is no longer sufficient; we must go beyond to actively reduce atmospheric CO_2 levels—an incredibly ambitious but essential goal."**

The urgency of tackling climate change and developing a circular, sustainable economy has never been greater. This transformation demands the most significant shift in human existence since the Industrial Revolution and must be underpinned by the principles of a Just Transition. There is an irony that decarbonisation intrinsically relies on multiple industries which are, in their current forms, carbon intensive. Metals, mining, cement, chemicals, manufacturing and the shipping of materials to where they are needed depends heavily on carbon-based power. Add to this, the huge amount of new infrastructure needed - solar farms, wind turbines, pipelines, new industrial assets etc., - and it becomes clear that industrial growth is essential for decarbonisation.

Recent global events have illustrated that the option of "turning off the taps" to fossil fuels is simply not feasible. Fossil fuels are so intrinsic to the global economy that it is impossible to begin to decarbonise without recognising that to do so will, for a period of time, rely on their use to jump-start the transition. Renewable electricity simply cannot be scaled up quickly enough to meet immediate needs.

Furthermore, achieving net zero is no longer sufficient; there is already too much CO_2 in the atmosphere. We must go beyond net zero and tip the scales back to actively reduce atmospheric CO_2 levels—an incredibly ambitious but essential goal.

Carbon Capture and Storage (CCS) is a vital tool in the journey to this sustainable future. CCS offers the means to directly abate CO_2 emissions from the carbon intensive industries that are essential to kick-starting the sustainable economy. CCS also enables the rapid and large-scale delivery of the hydrogen and net zero liquid fuels economy, acknowledging that renewables are primarily needed to decarbonise electricity. Direct Air Capture (DAC) will also play a vital role in indirectly capturing CO_2 from sources that cannot easily transition away from fossil fuels including domestic, commercial and transportation sources. Ultimately DAC will also be essential in the eventual reduction of CO_2 concentrations in the atmosphere.

CCS is not new, the technologies used are proven, and large-scale delivery is entirely achievable with the right financial, policy and regulatory frameworks in place. However, CCS does face challenges, including novel emissions, the need to deliver multiple projects on an unprecedented scale and the need to consider Just Transition. Despite these challenges, none are insurmountable, especially with the host of innovations that are coming from the fertile minds of academics and scientists. Ultimately CCS is only part of the answer. The solution is not an either/or scenario but a recognition that every tool in the toolbox is necessary to avoid the worst effects of climate change.

Capturing the Future: How C-Capture's Innovation Can Lead the UK to Net Zero Industry

Tom White
Chief Executive Officer
C-Capture

C-Capture

> **"Winning the industrial decarbonisation race is a once-in-a-generation opportunity for economic growth."**

Accelerating the adoption of energy-efficient, next-generation carbon capture technology is essential to avoid locking UK industry into long-term, high-cost decarbonisation pathways. This ensures global competitiveness for UK industry, where post-2035, there will only be a market for net-zero products. We need an industrial strategy to invest in and expand a UK supply chain of technology, skills, and components to deliver cost-effective modular carbon capture solutions rapidly. Winning the industrial decarbonisation race is a once-in-a-generation opportunity for economic growth.

Climate change, created by over a century of unsustainable practices, has no silver bullet. Carbon capture is crucial to limit global temperature increases to 1.5 degrees Celsius. Decarbonising global industry, which emits around 40 billion tonnes of CO_2 annually, is one of the most pressing global challenges we face today. Certain materials—such as cement, steel and glass—cannot currently be produced without emitting CO_2, making these sectors significant contributors to global CO_2 emissions. Decarbonising the industrial sector is imperative to achieving net zero. Without carbon capture, even renewable industries will maintain a large carbon footprint.

C-Capture's innovative, proprietary carbon capture technology removes CO_2 from flue gas emissions, preventing its release into the atmosphere. The CO_2 can then be stored or utilised. Our immediate goal is to build and operate first-of-a-kind prototype commercial-scale capture units in our target markets, to prove our technology and unlock private sector investment. Our ambition is to enable a UK gigafactory to manufacture modular carbon capture plants to our design under licence, halving the current costs of decarbonising UK industry. Replicating this model internationally will help us to achieve our target of capturing 1 billion tonnes of CO_2 per year by 2050.

It is imperative to form consortiums with emitters and supply chain partners within industrial clusters to finance, design, build, and operate a UK gigafactory fabricating modular carbon capture plants. This will lower costs, drive demand, and unlock investment for global rollout, invigorating the UK steel industry and maximising green jobs. It will also enable UK manufacturers to scale up production of high-value components, further driving down costs.

However, there is no current market mechanism to enable private sector investment in first-of-a-kind commercial-scale prototypes before the sequestration infrastructure of Track-1 is ready, estimated by 2030. Developers of next-generation carbon capture technologies like C-Capture, are seeking supportive revenue mechanisms to supply CO_2 captured by proto-type capture units to the under-supplied UK merchant CO_2 market. This is to unlock private sector capital investment. UK consumers currently pay a premium for imported liquified CO_2. The required support mechanism would only need to be short-term, until UK sequestration infrastructure is in place.

If next-generation technology developers cannot secure support for commercial demonstrators in the UK, we will have to explore overseas markets. The US Inflation Reduction Act makes this an attractive option, and other countries are actively looking to attract carbon capture technologies. This would be a missed opportunity for the UK to lead in the decarbonisation of industry, become a global leader in manufacturing decarbonised products, stimulate economic growth, and create green jobs. Carbon capture is essential for reaching net zero, buying time to develop and implement new decarbonised methods for providing the products and services essential to society's functioning.

CCUS: The Inescapable Key to Achieving Net Zero

Laura Gillions
VP Marketing & Public Affairs
Carbon Clean

carbon clean
TECHNOLOGY TO ACHIEVE 'NET ZERO'

"Simply put, there is no net zero without carbon capture. Momentum is building, but it's now time to stop debating and start delivering at scale."

The case for Carbon Capture, Utilisation and Storage (CCUS) is compelling. Described as "essential" and "inescapable" by the United Nations Economic Commission for Europe (UNECE) and the International Energy Agency (IEA) respectively, it is a necessity for decarbonising hard-to-abate industries. The crucial role of CCUS in achieving net zero was also recognised in the COP28 final agreement in December 2023.

The CCUS sector has grown substantially in the past few years. But the challenge now is to accelerate widespread adoption and at-scale deployment. The role of Government in achieving this cannot be overstated. And it starts with the avoidance of political short termism. Government support is crucial in establishing a stable regulatory environment that incentivises private sector investment. It's important to reward first-movers and early adopters. Most of all, business needs to have confidence that the regulatory environment is predictable and stable throughout the project lifecycle, from inception to delivery.

Fostering competitiveness stimulates entrepreneurial thinking. But rather than holding formal competitions, imposing artificial limits or selecting individual projects to support, it would be far more beneficial to maximise the number of viable projects. Setting clear policy criteria will enable projects that are financially viable to proceed on a first-come, first-served basis.

Other challenges still must be addressed, however. Reducing the cost of power for industrial customers is vital to cut the cost of carbon capture. Reforming the planning and permitting system is also essential so that projects move forward in a swifter, smoother manner.

Technical innovation, on the other hand, is happening at pace. Carbon Clean is leading the transition away from a costly, bespoke engineered approach that takes months, even years, to deliver. In order for carbon capture deployment rates to increase, the cost of technology must come down.

We are radically improving the economics of carbon capture through our modular CycloneCC technology, which overcomes the cost and space barriers that have to date held back widescale carbon capture deployment.

Modularisation holds the key to making carbon capture financially and logistically viable for hard-to-abate industries. CycloneCC's plug and play, "Lego-block" design makes it easy for emitters to add carbon capture units in line with their decarbonisation strategies. Our prefabricated, standardised, modular approach reduces manufacturing time and results in speedier on-site deployment and commissioning, with minimal site disruption. We're now focused on commercialising the technology so it can be easily replicable, mass produced and deployed at scale.

Investing strategically in CCUS will enable the UK to develop a world-leading position in the transition to a low-carbon economy. The opportunity is huge, supporting a range of political goals, from economic growth and export potential to nationwide skills development and job creation.

Simply put, there is no net zero without carbon capture. Momentum is building in the climate solutions business, especially in the CCUS space. But it's now time to stop debating the value of CCUS and deliver globally at scale.

Investing in Energy Transition Jobs of the Future: Wood's Role in Recruiting and Training Skilled Engineers

Suzanne Ferguson
Carbon Capture & Hydrogen Production Consultant
Wood

"The energy transition offers a unique opportunity to invest in our teams and inspire the engineers of the future, driving exciting projects that combat climate change with cutting-edge technology."

With 35,000 professionals, across 60 countries, Wood is one of the world's leading consulting and engineering companies operating across energy and materials markets. We understand first-hand that the energy transition requires a huge rate and volume of project delivery to meet the current levels of government targets for Carbon Capture and Storage (CCS), and low carbon hydrogen. If net zero targets in 2030, 2050 or further into the future are to be met, consultants and contractors focused on energy transition projects are unlikely to be exposed to significant "downturns" in workload.

A major challenge for the consulting and contracting industry has historically been the cyclical nature of work based heavily on the oil and gas industry, or a limited range of industrial sectors. This leaves us vulnerable to external events that might cause a sector-wide reduction in new capital projects, driving redundancies, followed by waves of new project investments. Subsequently, it can be challenging to find experienced engineers to design and build new projects.

The long-term outlook for a very high workload is a blessing for contracting and consulting because it provides certainty that investing in the development and expertise of our teams is paramount. It forces us to consider where to direct investment to ensure we are bringing forward the engineers of the future and to provide our people with varied and fulfilling work. However, it is important to note that since net zero was signed into law, we are already finding it challenging to recruit, train and retain skilled engineers for even the early phase of engineering works, let alone large-scale construction.

As a historically oil and gas focused contracting company, our experience has been that fewer young people, and notably fewer young women, are choosing engineering, contracting or consulting careers in this industry, perhaps due to uncertainty in the future of oil and gas or the desire to not be associated with polluting fossil fuels. But with many exciting projects focused on combating climate change, using innovative technologies at the cutting edge of science, we believe that the prospect of working with us has become far more attractive, and importantly could help to counter the trend of people not choosing engineering as a career.

To help realise this, we must do more to communicate how important, exciting and rewarding the careers are in carbon capture, transport, storage and use, as well as low carbon hydrogen and the circular economy. Raising the profile of the many and varied technological solutions we need to mitigate climate change, and the brilliant teams already working on them, could help inspire the scientists and engineers of the future.

Unlocking the Future: The Journey to Gigaton-Scale CO_2 Storage

Sarah Gasda
Research Director Computational Geosciences and Modelling
NORCE

"A rising tide lifts all boats – sharing and collaborating will ensure a smooth path to gigaton storage."

CO_2 storage is a proven technology, with over 200 Mt stored in dozens of projects worldwide. These include small pilot projects and larger industrial-scale demonstrations carried out in Europe, North America, Asia, and Australia. Two of the longest running projects on the Norwegian continental shelf have operated continuously for nearly 30 years, accounting for more than 15 percent of stored CO_2 globally.

Although 200 million tonnes (Mt) of CO_2 is miniscule in terms of the 37,000 Mt of CO_2 emitted each year, it's a crucial milestone. This establishes the fact that deep porous rocks are inherently suitable for permanent CO_2 storage. Such rocks are abundant in virtually every corner of the globe, indicating that Carbon Capture and Storage (CCS) has the potential to be deployed where and when it is needed. 96 percent of worldwide storage potential is still undiscovered. For Europe, this translates to 127,000 Mt of undiscovered potential.

CO_2 storage is, by all measures, a success story with an established track record in storage management of zero leakages or anomalous events across 26 unique projects. This success is no accident – it combines more than 50 years of knowledge inherited from the oil and gas industry with concerted efforts from research and academia to close new knowledge gaps.

Despite years of experience, it is impossible to have perfect knowledge of the deep underground. In other words, we need to be open to learning by doing. Each new industry project provides valuable data to strengthen the knowledge base, making each subsequent project more efficient and safer than the previous one. Projects can be planned safely, but we should expect the "unexpected" and use the new data to calibrate and fine-tune industry practice.

In this early stage of industrial CCS, errors can erode public confidence. We have to get it right! As a result, these first projects are likely over-engineered to be on the safe side. Ultimately, all new projects will help eliminate these surplus design features, streamline resources, and eliminate unnecessary overhead. Safe and effective storage at lower cost will be a win-win.

There are no foreseen barriers to massive acceleration to gigatonnes stored by 2050.

New investments and growing commercial interest in Europe and North America are encouraging signs that the long-suffering business model for CCS is improving. Despite this, the current pace is unequivocally too slow. To put it in perspective, the world needs several hundred megaton-scale storage projects in operation by mid-century to decarbonise hard-to-abate industry sectors.

Unlocking the enormous storage potential demands a new mindset, transitioning from single isolated projects to many interconnected storage sites around shared infrastructure.

The key to success is openness — between projects, with regulators, with researchers, and towards the public. A rising tide lifts all boats – sharing and collaborating will ensure a smooth path to gigaton storage.

The UK's Role in Unlocking Europe's CO_2 Storage Potential

Els Jooris
Business Opportunity Manager CCS
Shell

"By overcoming legal barriers, we can unlock Europe's CCS potential."

One of the challenges hindering global Carbon Capture and Storage (CCS) deployment at pace is international legal barriers, particularly related to cross-border transport and storage of CO_2.

The UK stands out as a prime CCS storage location due to its estimated 78 gigatonnes of CO_2 storage capacity. This accounts for almost one-third of Europe's total capacity and includes depleted hydrocarbon reservoirs and saline aquifers. The well-characterised geological setting of the UK continental shelf, along with existing oil and gas infrastructure, could offer a cost-effective pathway for CO_2 transport and storage. However, a fundamental barrier exists: the lack of a framework enabling CO_2 export between the EU and the UK. Establishing such a framework would create conditions for a competitive integrated European storage market, benefiting Europe by driving down costs and accelerating industrial decarbonisation efforts.

A Europe-wide competitive market for CO_2 storage is crucial. Meeting the EU's climate targets will require storing at least 250 million tonnes (Mt) of CO_2 per year by 2040 and 450 Mt by 2050.

To achieve the necessary capacity for decarbonisation and reduce storage costs for emitters, Europe must deploy enough operational CO_2 storage sites for the near future and for 2050. This storage is not only required for industrial emitters but also to accommodate greenhouse gas removals which will be required to achieve net zero by 2050. This underscores the importance of a competitive European storage market that includes the EU and the UK. To create a framework between the EU and the UK, two key issues need to be resolved.

The first issue is to enable carbon capture projects in the EU to be exempted from the need to surrender allowances under the EU Emissions Trading System (ETS) when storing CO_2 in the UK – i.e. for CO_2 captured in the EU to be considered 'not emitted' when stored in the UK (and vice-versa). The most important first step would be an agreement in a suitable form between the EU and the UK allowing for mutual recognition of permanent carbon storage in each other's jurisdiction.

The second issue is to agree a common standard for storage sites. The CCS Directive and equivalent UK 2010 CO_2 storage regulations provide a robust and aligned basis for the appraisal and characterisation of CO_2 storage sites. If the UK maintains a legislative requirement for transport & storage operators to follow the CCS Directive, which was originally implemented into UK law, this could be one way to future-proof a common basis of storage site suitability for the import of CO_2 from the EU. As a source of good practice, with detailed implementation guidance, this should not add a material burden to UK CO_2 storage developers' appraisal and permit development work programmes and may be viewed as a comprehensive and standard set of requirements for storage site suitability.

Implementing the necessary framework demands advocacy from all stakeholders. Achieving alignment between political stakeholders in the EU and the UK is paramount. By overcoming legal barriers, we can unlock Europe's CCS potential and pave the way for a sustainable, low-carbon future.

We have a unique opportunity in Europe to move the needle, but it will require collaboration, dedication, persistence and willingness to work together across legal barriers and boundaries.

Carbon Markets: A Necessary Tool for CCS Deployment?

Professor Niall Mac Dowell
Professor of Future Energy Systems
Imperial College London

Imperial College London

> **"Carbon prices are a necessary, but insufficient tool for initial deployment of CCS"**

The role and value of Carbon Capture and Storage (CCS) in climate change mitigation is recognised by many stakeholders; The International Energy Agency (IEA), the Intergovernmental Panel on Climate Change (IPCC), and the Climate Change Committee (CCC), all see an important role for the technology. Moreover, the scalable and permanent removal of CO_2 from the atmosphere via Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Capture (DAC) is also enabled by the deployment of CCS infrastructure.

However, steadily eroding carbon budgets notwithstanding, CCS has not yet been deployed at the scale required. At the time of writing, the UK, for example, has been attempting to deploy CCS for almost 20 years, and despite having come close previously, we have not yet been successful. The impediment is not technology; all elements of the value chain – capture, compression, transport, storage, and monitoring, reporting, and verification (MRV) of the store's integrity are all well-understood and commercially available today. The challenge is the lack of an investable business model and a bankable revenue stream.

It is in this context that carbon markets are often discussed; it is suggested that with a sufficiently high price on carbon, either as a tax or via a "cap and trade" scheme, CCS and other climate change mitigation pathways, will become economically viable. The challenge is that whilst many parts of the world have carbon pricing instruments of one kind or another (ETS, carbon tax, etc.), the price points of these instruments are often very low, are quite volatile, and are exposed to substantial political risk – a change of administration can cause prices to fall substantially.

As an example of this volatility, in March 2020 the EU ETS was just over €15 per tonne of CO_2, and by February 2024, it had increased to €100 per tonne of CO_2, and by February 2024 the price had reduced again to €52 per tonne of CO_2. Obviously, this level of volatility is disconcerting from the perspective of capital-intensive investments such as CCS, and it is to address this risk that the concept of Carbon Contracts for Difference (CCfD) has emerged in the EU, Canada, and also here in the UK. This approach stabilises the carbon price at a level sufficient to support investment or issuing debt.

Another way of achieving a similar outcome is, e.g., via a tax credit such as the now famous 45Q credit that is part of the USA's landmark Inflation Reduction Act, (IRA). As this instrument manifests as a direct payment from the US government to qualifying projects, it constitutes an eminently bankable revenue stream and can therefore be readily used in the kinds of cash flow analyses typically used to justify a debt issuance.

However, both CCfDs and tax credits have their downsides. Tax credits are available at a fixed level - $85 per tonne of CO_2 for 45Q, and it remains to be seen exactly how many tonnes of CO_2 will be sequestered at this price point. The CCfD is more flexible in terms of price point, but the strike price does have to be bilaterally negotiated directly with government, which can be time consuming.

Ultimately, both CCfDs and tax credits have a fixed tenor – typically no more than 15 years – which will inevitably be less than the physical life or the asset. This inevitably begs the question of what happens next. Thus, the long-term solution may be a transition to something closer to a regulatory paradigm, such as an emissions performance standard (EPS), where carbon pollution is regulated in a manner closer to that of other pollutants so as to avoid rebound effects.

Scaling Up Greenhouse Gas Removals: The Industrial and Climate Imperative

Peter Freudenstein
Senior Climate Policy Manager
Climeworks

"To fully realise the benefits of GGRs across climate, economy, and society, a concerted effort between the public and private sectors is necessary, leveraging financing to reduce costs and attract new investors, ultimately charting a path towards net zero."

The Intergovernmental Panel on Climate Change (IPCC) and the climate science community have been explicit that removing gigatons of CO_2 from the atmosphere annually, alongside ambitious emissions reductions, is vital to achieving the goals of the Paris Agreement. Greenhouse Gas Removal (GGR) approaches play a crucial role in the wider carbon capture ecosystem by neutralising unavoidable and historical emissions to reach global net zero by 2050 and net-negative emissions thereafter. Therefore, a portfolio approach to GGRs is needed with an increasing focus on GGRs achieving geological storage-like permanence. Engineered approaches like Direct Air Capture with Storage (DACS) or Bioenergy with Carbon Capture and Storage (BECCS) are uniquely positioned to achieve this.

Governments are now increasingly recognising the urgency and opportunity of scaling this industry. They are setting specific targets like the UK's goal of deploying 5 million tonnes (Mt) per year of engineered removals by 2030 and creating new markets by preparing the groundwork for the eventual integration of GGRs into compliance markets like the EU Emissions Trading System (ETS). While more is needed to stand up a whole new industry, they are dedicating important commercialisation funding beyond research, development, and demonstration, for example in the form of the US Department of Energy's Direct Air Capture (DAC) Hub programme. This exemplary programme dedicates $3.5 billion to enabling 4 DAC hubs in the US, kick-starting the cost reduction journey for DACS.

Beyond the immediate climate benefits there's a clear industrial logic behind engineered GGRs. The industry can generate a substantial number of jobs, relying on skills and labour already present in existing industries like manufacturing or chemicals. A recent report by the US research group Rhodium Group finds that a 1 Mt per year DACS facility can generate 840-1500 temporary and 240-450 permanent jobs. It also estimates a total required investment of $1 to $1.7 billion to construct the plant, resulting in substantial local value creation via increased tax revenues, and the development/onshoring of a new industry.[1] GGRs are also uniquely positioned to foster new private-public partnerships. A clear climate mandate for a growing industry coupled with future economic promise has led to innovative commercial ideas. These include starting up a global buyers' club for GGR of over $1 billion based on an advanced market commitment model (previously used to commercialise crucial medical treatments) to match early government funding with philanthropic finance.

These early collaborative efforts have already shown promising progress. For instance, Climeworks launched the world's largest commercial DACS plant "Mammoth," in Iceland in May 2024, driven by strong demand from the voluntary carbon market. It is now developing Project Cypress in Louisiana, US, with a $600 million backing from the US government. To fully realise the benefits of GGRs across climate, economy, and society, a concerted effort between the public and private sectors is necessary. This will help leverage financing to further reduce costs and attract the next wave of customers and investors, ultimately charting a path towards net zero.

[1] Source: https://rhg.com/wp-content/uploads/2024/04/The-Economic-Benefits-of-Direct-Air-Capture-Hubs.pdf

Bridging the Knowledge Gap: Public Awareness and Acceptance of CCS in the UK

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THE UNIVERSITY of EDINBURGH

"Even though support for CCS projects is higher than opposition, the visibility of active opposition makes it appear nearly double the support."

Although Carbon Capture and Storage (CCS) has been deployed commercially for nearly three decades, public awareness remains low. Nevertheless, social resistance to CCS projects, for example in the Netherlands and Germany, has shown the importance of public acceptance for determining whether projects will advance or not. Recent research conducted by three Scottish universities and the British Geological Survey sought to establish a baseline for social attitudes and beliefs towards CCS in the UK. The research included a representative survey of 5,125 UK residents in June 2023.

Unsurprisingly, few people in the UK have heard of carbon storage or communicated about it. Fully half of the representative sample of the British public have never even heard of geologic storage of CO_2, and another quarter have only heard of it, but know nothing about it. The research also included analysis of social media. There are some temporal peaks in Twitter discussion of CCS (e.g., aligned with major government policy announcements, and COP26 in Glasgow), but these pass quickly, with little change in attention to the topic over time. The same is true of Google searches via Google Trends. There is no evidence for sustained public attention to CCS via social media in the UK.

Despite the low awareness, on aggregate, the survey respondents supported CCS projects in the UK, including CCS captured from difficult to decarbonise industries, waste-to-energy projects, Direct Air Carbon Capture and Storage (DACCS), hydrogen projects, and gas-fired power stations. Overall, 41.3% of the survey sample stated they would support a CCS project proposed in their area, and 30.1% stated they would oppose it (28.6% were indifferent to the project). Nevertheless, 14.5% stated they would actively oppose the project, whilst only 8.0% would actively support it. Active support/opposition included things like contacting politicians, speaking to family/friends, and offering comments on social media or to newspapers. This means that even though the amount of people supporting a prospective project is a third higher than those opposing it, what this could look like to an outside observer, who only sees behaviours and not attitudes, is that opposition is apparently nearly double support.

The disparity in attitudes and intended behaviours towards CCS clearly raises questions about what can be done in terms of communication. One suggestion is that people interested in raising awareness of carbon storage should proactively communicate with political leaders and civil servants. The survey data suggest that people who oppose CCS projects are over 2.5 times more likely to contact politicians about the project, compared with people who support the projects. Clear physical science and social science on the geophysical and social realities of how the rocks will respond to the CO_2, and how the public feels about the project, would help political leaders make informed decisions.

Additionally, open comments in the survey, particularly from those individuals who opposed CCS projects, revealed concern about not having enough knowledge about long-term impacts of carbon storage. A principled discussion might be needed societally about how much knowledge is necessary before one should act, alongside the reality that not taking action to move forward with carbon storage projects is still an action with its own trade-offs (associated with not sequestering carbon).

CCS: Ensuring Sustainability is Embedded Across a Very Diverse Landscape

Dr Jen Roberts
Senior Lecturer
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"Complexity and nuance are not excuses for inaction—CCS is critical to delivering deep emission reductions and fostering a sustainable future."

Carbon Capture and Storage (CCS) is an umbrella term that refers to a very diverse array of technologies, applications, and developments at different scales.

When talking about CCS and its role in enabling a sustainable future, it helps to be specific. This is because sustainability is much more than simply carbon emissions, and sustainable transitions involve more than technological solutions. Sustainability includes everything from greenhouse gas emissions to fair and inclusive jobs, demand on resources such as energy and water, biodiversity net gain, justice, public health and community wealth building.

The diversity of technologies, applications, and developments across the spectrum of CCS means that the interactions between CCS and these different dimensions of sustainability are very diverse, too. It also means that CCS may differ greatly in the benefits that a CCS development can offer - and to whom.

For any and all of its forms, it is important to ensure that CCS is developed in a way that delivers emissions reduction or carbon removals alongside, and facilitates - and integrates with - deep and long-lasting societal transformation.

To add further complexity, some aspects of sustainability are very sensitive to place. Therefore, what is appropriate and sustainable CCS development in one location, industry or application may not be as sustainable, or sustainable at all, in a different context.

There is an important difference between CCS in principle and CCS in practice. How a CCS project 'on the ground' is decided on, designed, delivered and operated – and how these projects connect with other transformations – really matter. We have learnt enough from technology development and implementation to know that some solutions might be acceptable in principle, but in practice projects are not welcomed where developments are not transparent, developers are not trusted, projects don't align with community priorities, nor are perceived to bring benefits to climate or community.

A CCS project 'done well' could support sustainable transition within a community, region, or country. CCUS not 'done well' may hinder fair transition and the societal transformation that is required for a sustainable future. Best practice principles across multiple dimensions of sustainability should be embedded through projects in a way that is appropriate to place and context.

Whilst these complexities are important, and important to navigate, complexity and nuance are not an excuse for inaction. CCS is critical to deliver deep emission reductions and carbon removals, and is one small part of many solutions that are needed for us to live within planetary boundaries to ensure that humanity can continue to develop and thrive for generations to come.

Closing Remarks

Sir David King
Founder & Chair
Climate Crisis Advisory Group (CCAG)

"While transitioning away from fossil fuels is crucial, capturing and sequestering CO_2 at scale is increasingly essential. The UK's commitment to net zero emissions, now shared by over half the world's nations, underscores this need."

Earth's climate systems are changing more rapidly than anticipated even a decade ago. Over the past year and a half, land and ocean temperatures have soared unexpectedly, with land temperatures exceeding the 1.5°C mark. Greenland now loses ice at a staggering rate of 30 million tonnes (Mt) an hour, compared to 50 Mt a year 40 years ago. Extreme climate events have become the norm, causing global loss of life and economic damage.

Time is no longer on our side. Every effort must be made to accelerate actions ensuring a manageable future for humanity. While transitioning away from fossil fuels is crucial, capturing and sequestering CO_2 at scale is increasingly essential. The UK's commitment to net zero emissions, now shared by over half the world's nations, underscores this need. Although reducing global emissions by 90% is possible, the remaining 10% must be captured and sequestered—hence, 'net zero'.

Reflecting on the causes of escalating climate challenges, we must abandon the concept of a 'Carbon Budget' introduced by the Intergovernmental Panel on Climate Change (IPCC) before the 2015 Paris Agreement. This budget implied a safe future if we stayed within its limits en route to net zero emissions. We now understand that climate tipping points can lead to irreversible changes.

Sound climate science has emerged showing that the optimal atmospheric CO_2 level for a manageable future for humanity should be no more than 350 parts per million (ppm). Today's level is 427 ppm, compared to the pre-industrial 275 ppm. The situation is clear: we must not only reduce emissions deeply and rapidly but also remove excess greenhouse gases already in the atmosphere, aiming beyond net zero.

It would be optimal to have a CO_2 emissions price as a standard in all countries; a tax on all CO_2 emissions to encourage the transition away from fossil fuels. This tax could be used as a resource for Carbon Capture and Storage (CCS), and optimally the carbon price could be set at a fraction more than the cost of capture and storage, encouraging the transition to non-fossil-fuel usage.

CCUS Voices presents crucial insights from experts at the forefront of CCUS work. It highlights vital points for the UK and other governments to consider: the lack of investible business models with a bankable revenue stream, the need for a Europe-wide competitive model for CO_2 storage (including the UK), the necessity of reforming the planning and permitting system, and exploring the abundant deep porous rocks offering the potential to store 130 billion tons of CO_2 across Europe. Globally, we could achieve a storage rate of 10-15 billion tons per annum.

Ultimately, CCUS is not just a tool, but the linchpin for securing our planet's future.

Contributing Organisations

RWE

The leading power generator in the UK, and a leading renewables developer, generating enough power for around 12 million homes, with a diverse portfolio of gas, biomass, wind and hydro.

ERM

ERM is the largest global consultancy delivering environmental, health, safety, risk, and social impact services to help businesses sustainably manage their operations.

C-Capture

C-Capture is at the forefront of developing chemical processes for low-cost, scalable carbon capture technology to reduce industrial CO_2 emissions.

Carbon Clean

Carbon Clean is a leader in carbon capture technology, offering solutions that significantly lower the cost and complexity of capturing carbon emissions from industrial sources.

Wood

A global consultancy and engineering firm spearheading decarbonisation and digitalisation solutions across the energy and materials sectors to design and build a sustainable energy future.

NORCE

A Norwegian research institute that drives innovation through interdisciplinary research in energy, climate, health, technology, and society.

Shell

An international energy company transitioning from traditional fossil fuels to providing more sustainable energy solutions, including renewables and low-carbon technologies.

Imperial College London

A world-class research university known for its expertise in science, engineering, medicine, and business, particularly in addressing global challenges like climate change.

Climeworks

A pioneer in Direct Air Capture and Storage (DAC +S) technology, developing systems that remove CO_2 from the atmosphere for storage or reuse in sustainable products.

The University of Edinburgh

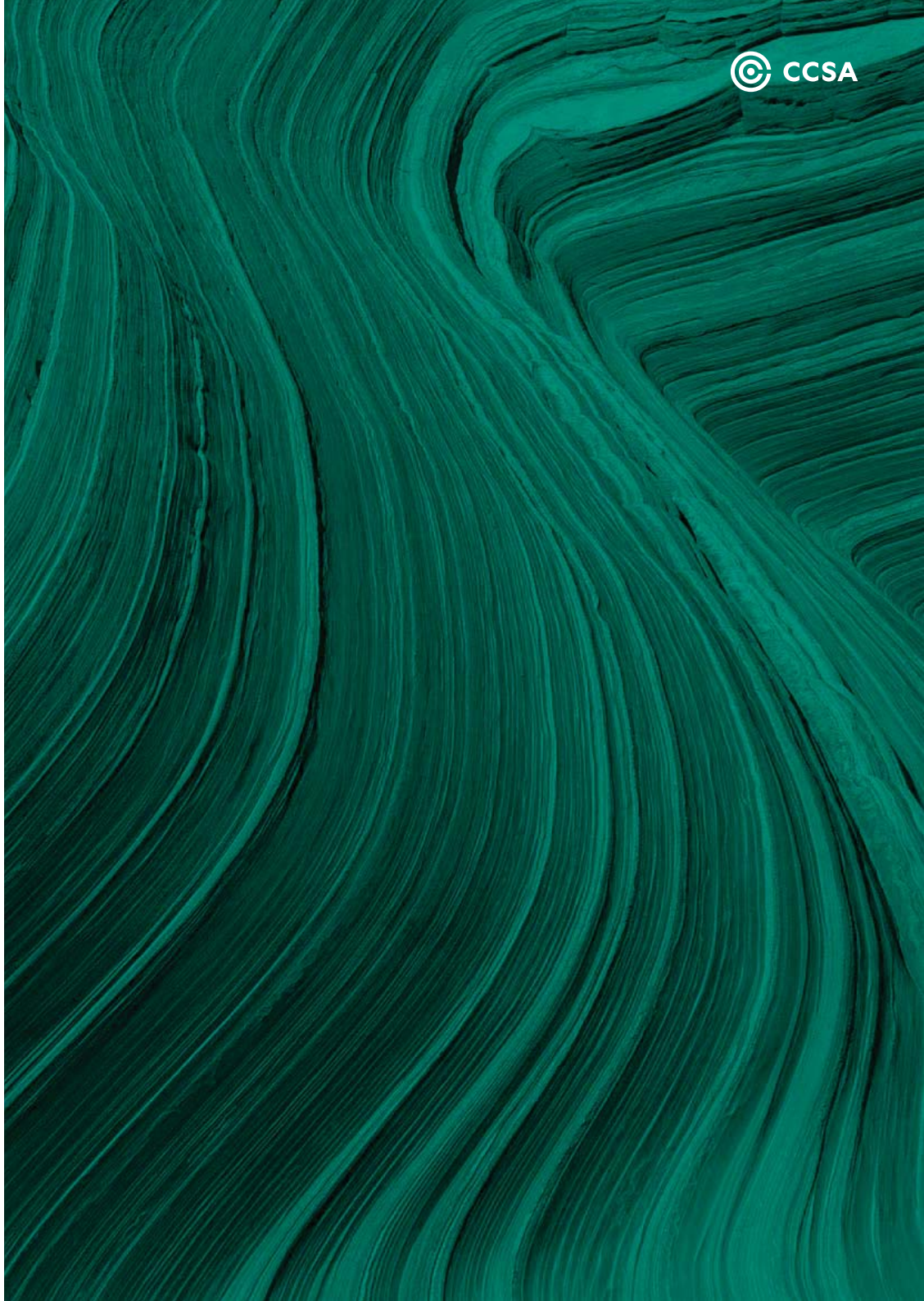
A world-class university renowned for its cutting-edge research and education, particularly in fields related to environmental science and sustainability.

Strathclyde University

A Scottish university known for its strong focus on engineering, technology, and business, with deep industry partnerships and a commitment to innovation.

Climate Crisis Advisory Group

An independent body of climate experts providing strategic advice and insights to support global efforts in mitigating and adapting to climate change.



CCSA

The Carbon Capture and Storage Association (CCSA) is the trade association focused on accelerating the commercial deployment of Carbon Capture, Utilisation & Storage (CCUS).

We work with our members, governments and other organisations to ensure CCUS is developed and deployed at the pace and scale necessary to meet net zero goals and deliver sustainable growth across regions and nations. The CCSA has over 120 member companies who are active in exploring and developing different applications of carbon capture, CO_2 transportation by pipeline, ship and rail, utilisation, geological storage, and other permanent storage solutions, end-users from the industrial, hydrogen and power sectors, as well as the supply chain, management, legal and financial consulting sectors.

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