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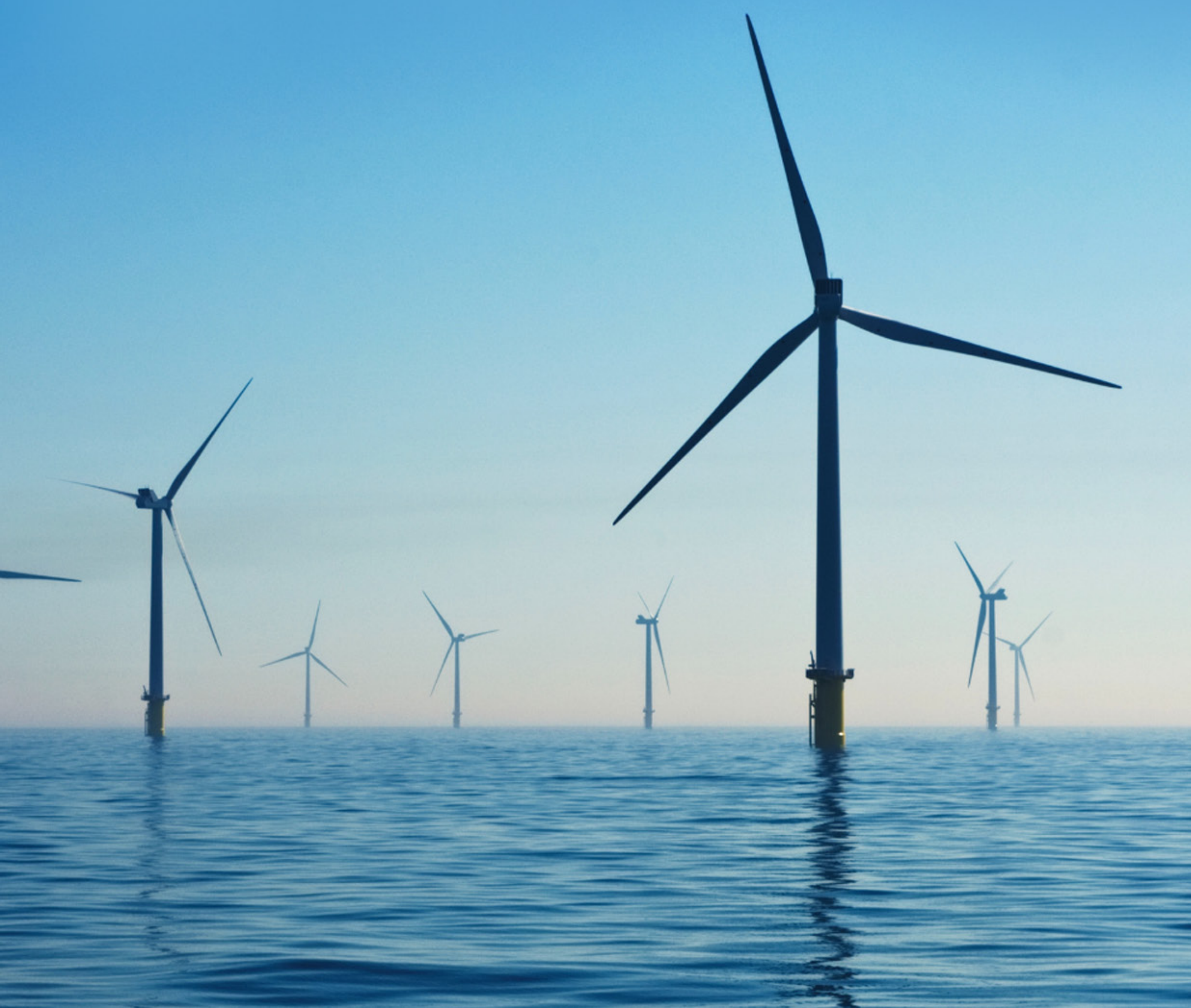
Green Finance Institute

What next for carbon dioxide removals?



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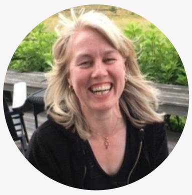

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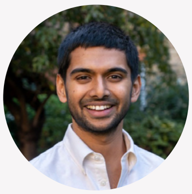

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Role of carbon dioxide removals (CDR) in net zero strategies

The very term 'net-zero' implies that some economic activity will be all but impossible to abate. So, whilst we must bear down on emissions, we need credible approaches to remove carbon from our atmosphere. Many worry that companies and governments could treat carbon removals as a substitute for decarbonisation in pursuit of net zero. As was the case with carbon offsets, avoiding this outcome and ensuring integrity will require careful monitoring and accountability. But durable removals are not like offsets: they are significantly more costly and they cannot scale to compensate for business as usual. Even with very deep and rapid cuts in emissions, scaling up durable carbon removals sufficiently to get to net zero will be a massive challenge.

The market opportunity

Even on optimistic mitigation scenarios, the challenge is huge. Across IPCC scenarios, 420-1,100 billion tonnes of CDR will be required cumulatively by 2100 to limit global warming to 1.5°C with no or limited overshoot. That translates to 5-16 billion tonnes a year by 2050. For context, the world emits around 40 billion tonnes of CO_2 every year. Estimates based on which sources of emissions will be most difficult to abate suggest a range of around 2 to 4 billion tonnes of CO_2 per year (representing 5-10% of current emissions), if we meet robust emission reduction targets.

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In the UK alone, the burgeoning Greenhouse Gas Removal (GGR) industry needs to remove 83-169 million tonnes of CO_2 every year by 2050, according to the Climate Change Committee. For context, the UK's emissions in 2019 were around 522 million tonnes. The UK government's Net Zero Strategy expects deployment of "engineered" removals to reach 5 million tonnes per year by 2030, potentially rising to 23 million tonnes by 2035 and reaching 75-81 million tonnes of CO_2 per year by 2050.

Recent analysis by Boston Consulting Group (BCG) estimates annual demand for durable carbon removal at around 40–200 million tonnes in 2030, translating into a $10-40 billion market opportunity in that timeframe and growing thereafter . Purchases of durable carbon removals in the voluntary market have taken off, growing to 3.4 million tonnes in H1-2023, a 5.6x increase over full year 2022. Most of this volume is accounted for by long-term ex ante offtake agreements, representing the main source of financing for carbon removal suppliers. Only 45,500 tonnes of durable carbon removals have been delivered[2].

> A $10-40 billion market opportunity.

The scale of CDR growth required is vast. To be on track to reach even the lowest estimates will require an exponential scale up to at least 40 million tonnes a year by 2030. That's a 1,000x increase over eight years and a 40-50% compound growth rate over the next 27 years. As a comparison, the total global energy consumption from renewable sources between 1990 and 2020 saw a 3x increase. Fortunately, there is increasing evidence of a willingness for investors to outlay capital; carbon funding grew 4 times between 2021 and 2022, with half the funding toward carbon removals[3].

1. https://web-assets.bcg.com/44/75/58c3126c4050b74ae75b037e9434/bcg-the-time-for-carbon-removal-has-come-sep-2023.pdf.
2. https://medium.com/@cdr_fyi/cdr-fyi-2023-mid-year-progress-report-656826b7e4cb
3. https://www.ctvc.co/40b-and-1-000-deals-in-2022-market-downtick/

Which technologies?

> Carbon removal is the process of purposefully removing carbon dioxide from the atmosphere and storing it durably.

Carbon removal is the process of purposefully removing carbon dioxide from the atmosphere and storing it durably . It encompasses a wide range of different technologies with different levels of maturity, durability, risks and price points.

Conventional nature-based removals, such as tree-planting, are cheap and very well-established, thanks to years of being traded on voluntary markets, but attract criticism forbeing fragile and unreliable. They also require significant land. The low cost of nature-based solutions has also contributed to widely publicised issues with respect to projects based on sometimes poor accounting – remediation efforts are now underway through the Integrity Council of Voluntary Carbon Markets (IC-VCM) and others.

Biochar currently dominates the market for durable carbon removals, due to its ease of production at a small scale, relatively low price and co-benefit as a fertiliser. While it can be produced widely (with different levels of durability based on method of production), it relies on waste biomass for which there is growing competition.

High-durability technologies such as direct air capture and storage (DACCS), bioenergy with carbon capture and storage (BECCS) and increasingly enhanced rock weathering (ERW) are starting to sell at commercial scale, as companies launch projects financed by selling future volumes to long-term off-takers. Prices are high, but deployment is expected to push them down the cost curve[4].

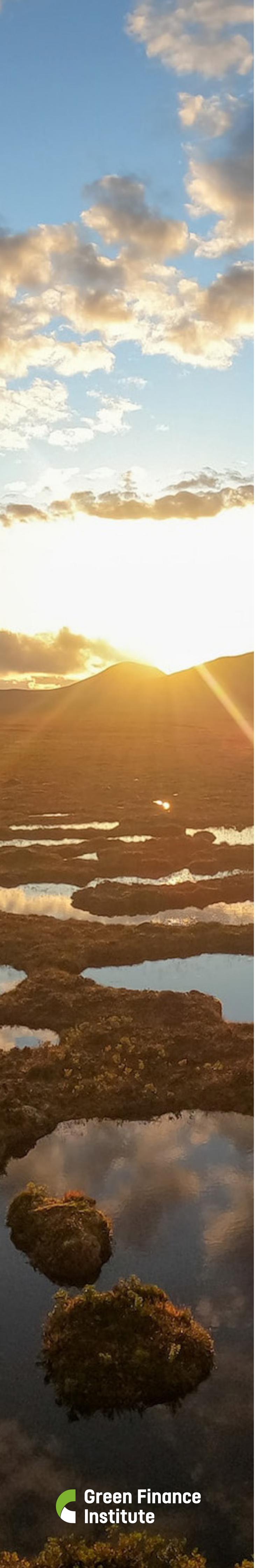
4. Note that while DACCS and BECCS use carbon capture and storage (CCS) to store carbon dioxide (CO_2) drawn down from the ambient atmosphere, most CCS stops point-source industrial emissions from entering the atmosphere and is, therefore, a reduction and not a removal

Other technologies, such as ocean alkalinity enhancement, or the use of atmospheric CO_2 in products such as cement, are still at pilot or demonstration phase. The Royal Academy of Engineering and the Royal Society's report on Greenhouse Gas (GHG) Removal lists 12 carbon removal methods that are estimated to have global potential on the billion tonnes of CO_2 scale[5]: These are set out in the appendix.

While many carbon removal methods hold promise of scale and a growing number of technologies are being tested, the uncertainties are great. They vary in cost, how much they can remove and in the resources they require, such as land, water and energy. Some carry risks, for instance due to costs of land conversion and biodiversity loss, particularly if deployed on very large scales. Some bring co-benefits, for instance generating power, reversing biodiversity loss or providing useful materials. There is still much scope for innovation and improvement, and some techniques will work better in some contexts than others. Some may never be successfully scaled.

Success will require key technologies to fall in cost, new business models to emerge, and new policies and legal and regulatory frameworks to be introduced, all in a manner that is acceptable to the public and socially robust[6].

5. Greenhouse gas removal, Royal Society and Royal Academy of Engineering, September 2018
6. https://co2re.org/



An approach to scale

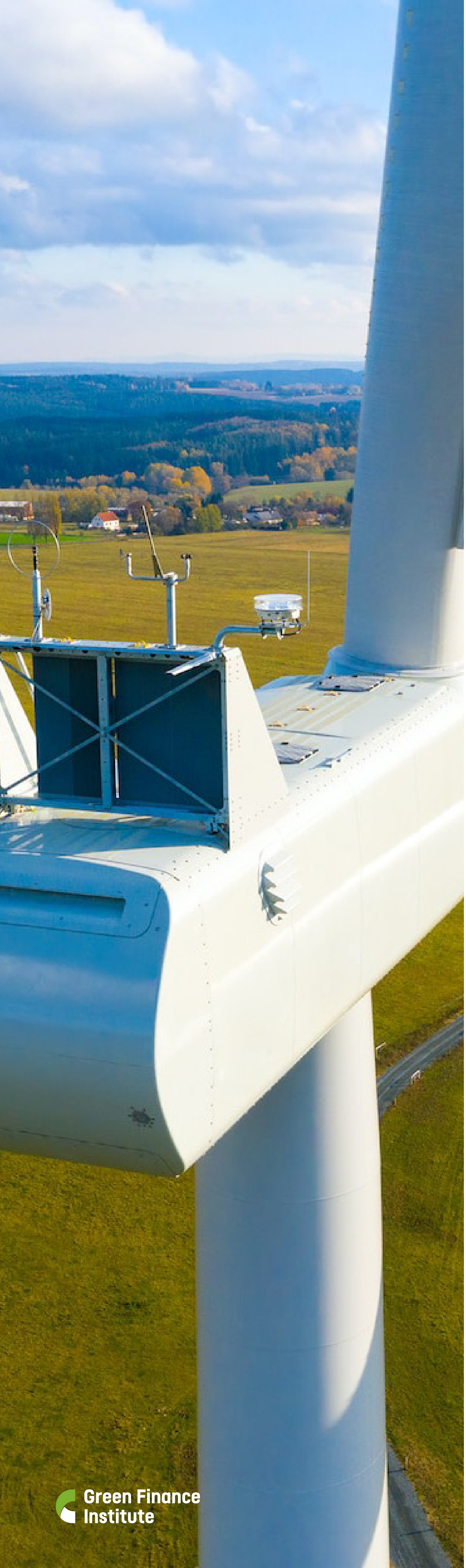
Given that time is short and the market is at a very early stage of innovation and development, it is sensible to look at a broad and diverse portfolio of CDRs, which help to maximise the removal potential and minimise over-reliance on any one technique. Scenarios from the Climate Change Committee show that a whole range of removal methods will likely be needed to reach net zero in the UK by 2050.

Our approach therefore needs to address barriers to scale of each scientifically viable technology. For some removal solutions, such as DACCS and BECCS, capex requirements can be incredibly high. While the scale of capital needed for these solutions is more aligned with infrastructure and debt capital, the risk profile is not. Other approaches, such as biochar and enhanced rock weathering, will likely need to be deployed by a dispersed set of actors – which bring distribution/aggregation rather than capex challenges. Thus, getting to scale assumes rapid learning and cost reductions. The market won't deliver this alone – government intervention will be needed.

In February 2023, the US Department of Energy announced $2.52 billion in funding for two carbon management programmes, for 'Carbon Capture Large-Scale Pilots' and 'Carbon Capture Demonstration Projects'. Separately, the US Department for Energy announced in August 2023 up to $1.2 billion for the development of the first two of four commercial-scale direct air capture facilities, in Texas and Louisiana. One is a joint venture between Battelle, Climeworks and Heirloom, while the other project will be run by 1PointFive, an Occidental subsidiary, in partnership with Carbon Engineering and Worley. Both intend to demonstrate removal of approximately 1 million tonnes of existing CO_2 from the atmosphere. In the EU, a range of public funds are available to support CCS deployment and a regulatory regime for carbon removals is actively in development[7].

The UK laid out a high-level greenhouse gas removal strategy in 2022 and is currently developing implementation details. The country offers a particular geological opportunity for DACCS and BECCS, due to the carbon storage potential of the North Sea. As of March 2023, the UK has a target to capture and store 20-30 million tonnes per year by 2030 through a mixture of BECCS and DACCS and is working on a business model to enable that. Public capital for the sector is available through the government's programme for building carbon capture, transport and storage infrastructure through support for carbon capture utilisation and storage (CCUS) clusters, originally capitalised with £1 billion and recently expanded by up to a further £20 billion[8]. Work is ongoing to explore the option of including carbon removals in the UK emissions trading system (ETS). There is also direct support for CDR R&D of £115m[9].

7. https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf
8. CCUS Net Zero Investment Roadmap (publishing.service.gov.uk)
9. CCUS Net Zero Investment Roadmap (publishing.service.gov.uk)



These are solid foundations from which to build a market framework that leverages private capital to accelerate the commercialisation of a portfolio of carbon removals. However more needs to be done to target key risks such as market risk and First of a Kind risk (FOAK) – providing adequate revenue certainty. Fortunately, lessons learned from developing business models for adjacent net zero sectors such as renewable energy and sustainable aviation fuel can support accelerated deployment of carbon removal.

In terms of solutions to overcome financing barriers, we propose deploying the following tools:

Policy clarity around technologies – The space is very confused, with different technologies and concepts conflated. The UK government has the opportunity to set up a transparent system to define what good looks like in each of these pathways and create a policy environment that is flexible enough to support multiple GGR technologies with appropriate market mechanisms.

Revenue certainty – Predictable demand signals are needed to address market risk. Policy can create these through regulated demand and/or policy incentives. The contracts for difference (CfDs) the UK Government has recently announced are an attractive option. Keeping policy flexible to support a range of solutions – perhaps for different tCO_2 price points – would be hugely beneficial.

Addressing other investment risks – Due to FOAK risks, tailored capital solutions will be needed to attract debt and lower costs of capital. While CfDs are a good way to clarify the revenue topline, guarantees, most likely from the public sector, will also be fundamental in bringing the banking sector onboard. This could be in the form of first loss capital or revenue guarantees.

Shaping standards – Standards for the durability of carbon removals are also key to market integrity, and should underpin any guarantee provisions. This is especially the case for nature-based solutions, such as the important but often overlooked solution presented by soil regeneration by way of example, but also for ensuring the climate effectiveness of emerging new approaches.

Moving ahead

The UK's GGR strategy is generating significant opportunities as it takes shape. In addition to grant support for the sector, announced in June to create a GGR business model based on a CfD approach linked to and harnessing the UK ETS, will provide revenue certainty[10]. It could also facilitate the development of definitions and principles to guide monitoring, reporting and verification (MRV), creating the conditions to fully develop a successful commercialisation framework that other jurisdictions can replicate.

While very attractive fiscal support has also been provided in the US, the UK cluster approach framework facilitates vital network brokering and can support a significantly wider range of developers and technological pathways.

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Thus, the UK seems an important test-bed for developing a holistic financing and policy package to support accelerated commercialisation of carbon removal technologies. This would include BECCS, DACCS, enhanced rock weathering and a range of ocean-based pathways. In parallel, the government also has room to build on existing market infrastructure for nature-based carbon removals (such as the Woodland Carbon Code).

We now need a 'go to market' strategy for each carbon dioxide removal technology, whilst creating the overarching market infrastructure to underpin the supply and demand for different technology solutions. This means deploying the toolkit above to deliver greater policy clarity and alongside it, adequate capital and revenue solutions to support scale.

We are developing a programme of work to support this approach and contribute to wider commercialisation efforts. We invite potential partners for delivery to get in touch to discuss how we can work together in a shared endeavour.

10. Direct Air Capture and other Greenhouse Gas Removal technologies competition - GOV.UK (www.gov.uk)

Appendix

Key CDRs technologies, as described by the Royal Academy of Engineering and the Royal Society. These are themselves broad categories covering a range of approaches. Some rely more on capturing carbon and storing it underground, whereas others rely more on agriculture and land use.

Biochar is a stable, long lived, charcoal-like product from the burning of biomass in the absence of oxygen (pyrolysis). Biochar is carbon-rich and can be spread on farmland, potentially storing carbon in the soil for an extended period. The Greenhouse Gas Removal Demonstrator (GGR-D) Programme's biochar project is looking to address the uncertainties concerning the extent and scope of deployment of biochar.

Bioenergy with carbon capture and storage (BECCS) involves using biomass for energy, capturing the CO_2 emissions and storing them, usually underground. The GGR-D Programme's perennial biomass crops project, PBC4GGR, is investigating the potential for plants like willow and miscanthus to support BECCS in the UK.

Building with biomass is about using forestry materials in building, which extends the time of carbon storage of natural biomass and enables additional forestry growth.

Direct air capture and carbon storage (DACCS) involves using engineered processes to capture atmospheric CO_2 for subsequent storage, usually underground. Carbon removal startup Charm Industrial is developing megaton scale DACCs, while Storegga's 'Dreamcatcher Project' is intended to lead towards a large-scale DAC plant in the UK by 2026.

Enhanced rock weathering is where crushed rocks spread on land react with CO_2 to remove it from the atmosphere. The GGR-D Programme's enhanced rock weathering project is exploring amending soils with crushed calcium and magnesium rich silicate rocks from quarry waste.

Forestation is about growing new trees and improving the management of existing forests. As forests grow they absorb CO_2 from the atmosphere and store it in living biomass, dead organic matter and soils. The GGR-D Programme's woodland creation and management project, NetZeroPlus, is gathering evidence, addressing knowledge gaps and allowing decision makers to explore the GGR consequences of different tree-planting options.

Habitat restoration can increase carbon storage in habitats such as peatlands and coastal wetlands. This also prevents carbon release through further degradation, often providing a number of other co-benefits. The GGR-D Programme's peatland restoration project, GGR-Peat, is working with natural processes to recreate, and where possible enhance, the environmental conditions that lead to peat formation.

Low-carbon concrete can be created by altering the constituents, manufacture or recycling method of concrete to increase its storage of CO_2. Seratech combines carbon dioxide with olivine to form silica which can be used as a supplementary cementing material. Use of the Seratech SCM replacing 35% of the Portland cement sequesters enough carbon dioxide to capture the CO_2 which arises from the production of the 65% of Portland cement that is not replaced, therefore producing net zero cement.

Mineral carbonation involves accelerating the conversion of silicate rocks to carbonates either above or below the surface to provide permanent storage for CO_2. A mineral carbonation demonstrator plant was approved in Australia in April 2023, with construction expected to commence this year. When complete, the demonstrator is intended to have a capacity for capturing and storing 1000-3000 tonnes of CO_2 annually.

Ocean alkalinity enhancement is increasing ocean concentration of ions like calcium to increase uptake of CO_2 into the ocean, and reverse acidification. Planetary Technology are conducting a study in Cornwall involving adding diluted magnesium hydroxide to water. Their estimate is the proposed addition will remove approximately 100 net tonnes of CO_2 from the atmosphere (accounting for all emissions associated with the trial activities themselves) – the equivalent of reversing emissions from a car driving 400,000km.

Ocean fertilisation is applying nutrients to the ocean to increase photosynthesis and remove atmospheric CO_2. The Natural Environment Research Council (NERC) have recently offered funding opportunities relating to 'Biological influence on future ocean storage of carbon', with projects currently being assessed and expected to start later this year.

Soil carbon sequestration involves changing agricultural practices such as tillage or crop rotations to increase the soil carbon content. The Plymouth Natural Grid programmed secured funding for a nature-based solutions project which includes carbon sequestration and storing across 8 sites using land management practices such as tree planting, flood management, pond creation and coppicing.

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