HM Government

Greenhouse Gas Removals

Summary of Responses to the Call for Evidence

October 2021

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Contents

Introduction

In December 2020, the Department for Business, Energy and Industrial Strategy (BEIS) and HM Treasury jointly launched a Call for Evidence on the role of Greenhouse Gas Removals (GGRs) in reaching net zero. It was published in light of the growing body of evidence, including the government's own analysis, showing that GGRs will be essential to balance residual emissions in hard-to-abate sectors in 2050, such as aviation, agriculture, and certain heavy industries.

The aim of the review was to strengthen the government's understanding of GGRs by inviting evidence and views on:

- the viability of different GGR techniques in the UK – including technology readiness levels, cost, deployment potential, lifecycle emissions, and wider constraints to deployment;
- the role of government in addressing market barriers and stimulating the development and deployment of GGRs; and
- supporting policies needed to enable deployment and scale-up, such as a robust framework for the monitoring, reporting and verification of negative emissions.

The Call for Evidence was launched 4 December 2020 and closed on 26 February 2021. The government received a total of 101 unique responses from a wide range of stakeholders, including GGR developers, NGOs, research institutes, trade associations, academics, and members of the public. A full breakdown of respondents is featured on the next page.

Along with our wider research, analysis, and stakeholder engagement, the evidence and views provided in these submissions have been used to inform the development of government policy on GGRs. The 'Government position and next steps' chapter of this document sets out the government's current view on the role of GGRs and some of the actions we will take to encourage their deployment. The remainder of the document provides a summary of responses to each of the 27 questions in the Call for Evidence.

This Summary of Responses is part of a wider package of policy documents on GGRs published in conjunction with the Net Zero Strategy, which also includes:

- An updated assessment of GGR methods and their potential deployment in the UK, conducted for BEIS by Element Energy and the UK Centre for Ecology and Hydrology.[1]
- The final report of a Task and Finish Group on GGR monitoring, reporting and verification (MRV), comprised of experts across government, industry, academia and regulatory services.[2]

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[1] Element Energy and UK Centre for Ecology and Hydrology (2021), 'Greenhouse Gas Removal Methods and Their Potential UK Deployment' (link)
[2] Task and Finish Group on Monitoring, Reporting and Verification of GGRs (2021), Final Report (link)

The government will publish a consultation on business models for engineered GGRs in Spring 2022. This will set out further details of our approach, including our preferred mechanisms to incentivise commercial deployment of GGR technologies from the mid-to-late 2020s.

Breakdown of respondents by type

The following table provides a breakdown of respondents to the Call for Evidence.

Type of respondent	**Number**
Think tanks, NGOs and Charities	16
GGR Developers	16
Research institutes and Universities	16
Trade associations	12
Members of the public	11*
Academics	7
Energy suppliers	6
Energy and climate consultants	4
Stakeholder coalitions	4
Public bodies	3
Campaign groups	2*
Standards / measurement organisation	2
Innovation centre	1
Political organisation	1
Total	**101**

*The government received identical responses from 557 members of the public as part of an online campaign, focusing on the role of BECCS as a greenhouse gas removal method. These submissions were counted only once in this analysis, under the 'campaign group' category.

Methodology

This document summarises the information and views provided in response to each question in the Call for Evidence. There were 27 questions in total, set out across 3 chapters. Some notes and caveats on the methodology of this document are provided below:

- A number of respondents provided a general submission and did not respond to individual questions. Evidence from these submissions was included in the summary of responses to specific questions where the information was deemed to be relevant.
- Numeric categories are used to give an indication of the number of respondents that expressed certain views. These categories relate to the proportion of respondents who answered a given question, rather than the proportion of total respondents to the Call for Evidence.
    - 'Most' is used when referring to more than 50 percent of respondents to a particular question.
    - 'Many' is used when referring to 25-50 percent of respondents to a particular question.
    - 'Several' is used when referring to 10-25 percent of respondents to a particular question.
    - 'A few' or 'a small number' are used when referring to <10 percent of respondents to a particular question.
- The summaries aim to provide an accurate sense of the weight of views. Nevertheless, this should be treated as a guide, given the open nature of the questions and the large number of varied suggestions we received.
- It is not practicable in this document to detail every single viewpoint or piece of evidence provided. However, all submissions have been reviewed and considered by the government in full.
- The views expressed by stakeholders are not government policy, and the information provided by respondents has not been corroborated or independently verified during the production of this document. A number of claims made by respondents were conflicting, contentious and/or not supported by evidence. They have been summarised without commentary from government.

Government position and next steps

The Call for Evidence submissions have been valuable in helping to inform the government's approach to GGR policy. BEIS and HM Treasury would like to thank all individuals and organisations who took the time to respond.

This section sets out the government's latest policy position on greenhouse gas removals, and the action we are taking to facilitate their development and deployment. It summarises the policy position outlined in the Net Zero Strategy, which provides further details of our approach.

Net zero will not be feasible without engineered GGRs

The Net Zero Strategy[3] sets out the ambitious policy action the government is taking to reduce emissions across all sectors of the economy. Nevertheless, the evidence is clear that there are likely to be residual emissions in 2050 from some of the hardest-to-decarbonise sectors, such as aviation, agriculture, and heavy industry. It is unlikely that novel zero-carbon technologies can be relied upon to eliminate the UK's emissions completely, while certain activities such as flying and meat/dairy consumption will continue to result in at least some level of carbon emissions over the coming decades.

Greenhouse gas removals (GGRs) will therefore be essential to compensate for the diminishing amounts of residual emissions that are difficult to eliminate entirely. This view is supported by whole systems analysis from organisations including the Climate Change Committee (CCC)[4], the Energy Systems Catapult[5], and the National Grid[6].

Nature-based GGR methods such as afforestation, habitat restoration, and soil carbon sequestration will play a vital role in removing CO_2 from the atmosphere by increasing carbon storage in natural sinks. However, these approaches alone cannot deliver removals at the pace and scale required to achieve the UK's climate goals, due to various factors such as land availability and the time taken for these techniques to sequester carbon.

Alongside nature-based solutions, a robust and comprehensive strategy for net zero will therefore require the development and deployment of engineered GGR technologies at scale – such as Direct Air Carbon Capture and Storage (DACCS), Bioenergy with Carbon Capture and Storage (BECCS), enhanced weathering, biochar, and seawater CO_2 removals.

BEIS modelling at the time of the Net Zero Strategy publication suggests that by 2050, between 75 and 81 $MtCO_2$/year of negative emissions from engineered removals will be required to offset residual emissions in hard-to-abate sectors.

[3] HM Government (2021), 'Net Zero Strategy'
[4] CCC (2020), 'The Sixth Carbon Budget – The UK's path to Net Zero' (link)
[5] Energy Systems Catapult (2020), 'Innovating to Net Zero: UK Net Zero Report' (link)
[6] National Grid (2020), 'Future Energy Scenarios' (link)

In acknowledging the contribution of GGRs to achieving net zero, we are not relaxing our commitment to drastically cut the emission of new greenhouse gases across the economy. The UK's sixth carbon budget sets a world-leading target to reduce greenhouse gas emissions by 78% by 2035 compared to 1990 levels, building on our new UN climate target to reduce emissions in 2030 by at least 68% against the same baseline.[7]

We are clear that the purpose of GGRs is to balance residual emissions from sectors that are unlikely to achieve full decarbonisation by 2050. They will not be a substitute for decisive action across the economy to reduce emissions, which will in turn reduce reliance on GGRs in the future. If optimised for specific purposes, certain GGR technologies can also assist hard-to-abate sectors to decarbonise; for instance, through the production of biofuels, biohydrogen, clean electricity, and carbon-negative cement. Nevertheless, the government recognises concerns around the potential 'mitigation deterrence' effect of GGRs, and the need to monitor where and how GGRs are deployed to ensure this does not occur.

GGR technologies remain at a pre-commercial scale of deployment, and few large-scale projects have been implemented worldwide. As a result, evidence around the scale-up potential and costs of engineered GGR solutions in the UK is uncertain and rapidly evolving. Yet the current evidence suggests that no single technology will provide a 'silver bullet' and that several GGR solutions will need to be scaled up in order to meet our climate targets.

The government will therefore take a portfolio approach to GGR deployment which enables the development and commercialisation of a mix of different technologies. We will ensure that our policy framework is flexible and responsive to innovation and learning, allowing the most feasible and cost-effective GGR pathway to emerge.

Our ambition is to position the UK as a global leader in GGR solutions, capitalising on new export opportunities while creating high-quality green jobs. We are especially well-placed to take a leading role in the global GGR market due to our academic and industry expertise, rapidly developing CCUS sector, and access to large volumes of geological CO_2 storage.

If world economies collectively reach net zero by 2050, the primary role of GGR methods could transition from balancing residual emissions to removing historical atmospheric carbon. This could present the opportunity to reverse some of the effects of global warming observed since the Industrial Revolution.

Government has an important role in catalysing investment in GGRs

It is clear that one of the fundamental barriers to GGR deployment is the lack of an established market or customer demand for engineered removals. GGR technologies are associated with high capital and operational costs, making private investment unattractive in the absence of policy incentives and a stable revenue stream for the provision of negative emissions. This

[7] 2030 Nationally Determine Contribution excludes international aviation and shipping. These emissions are included in the Sixth Carbon Budget.

emerged as a consistent theme through the Call for Evidence and the government's wider stakeholder engagement.

The CCC[8] and National Infrastructure Commission[9] have advised that government should develop policy mechanisms to support the demonstration of engineered GGRs at scale from the late 2020s, so that they can ramp up to achieve the necessary scales by 2050. Aside from supporting the delivery of the UK's carbon budgets, there are considerable strategic advantages to deploying commercial-scale GGR projects during the late 2020s and early 2030s. This would provide vital early experience of deploying novel technologies – reducing technology costs, generating technical improvements, and developing supply chains to enable scaling-up through the 2030s and 2040s.

To address prevailing market barriers, catalyse investment and kick-start the GGRs sector in the UK, we will consult on business models for engineered GGRs in Spring 2022. This will set out details of our preferred mechanisms to incentivise early investment and enable commercial demonstration of a range of GGR technologies from the mid-to-late 2020s. The consultation will consider how GGR incentives interact with policies and business models currently under development for CCUS, hydrogen production, sustainable aviation fuels and other relevant sectors, along with wider carbon pricing policy. It will also consider how near-term policy incentives can most effectively leverage private investment and enable a transition towards a market-led framework as the sector matures.

The government's long-term vision is to establish a liquid market for carbon removals, in which polluters have a strong policy or financial incentive to invest in GGRs in order to balance their remaining emissions. The UK Emissions Trading Scheme (ETS) is a possible market-based solution for stimulating investment in GGRs – moving us towards a single, integrated compliance market for carbon, with negative emissions supporting liquidity as the ETS allowance cap falls over time. GGR credits could function within an ETS market through, for instance, allowing polluting sectors to meet their obligations through the procurement of negative emissions alongside conventional abatement options.

In the Energy White Paper, the government committed to exploring how the UK ETS could incentivise the deployment of GGR technologies. Working in partnership with the Devolved Administrations, we aim to launch a call for evidence in the coming months on the role the UK ETS could have as a potential long-term market for GGRs. This will explore possible eligibility criteria for participation in the UK ETS, different types of GGR market design, and timings for when GGRs could be added to the market.

However, we recognise that a GGRs market will take time to establish, and there is likely to be a short-term role for government in providing bespoke support for initial projects to de-risk investment decisions and provide revenue certainty for technology developers.

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[8] CCC (2020), 'The Sixth Carbon Budget – Greenhouse gas removals' (link)
[9] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals' (link)

Whilst seeking to capitalise on the economic and environmental benefits of GGR development in the UK, we are also mindful of the risks of early deployment – including the cost of support for GGRs, technical and engineering challenges, and potential effects on consumers and businesses. Policy frameworks to enable the growth of the GGR sector will require careful design to guard against unintended effects. The cost of support for GGRs is likely to be shared between the public and private sector, and we will seek to develop an appropriate balance of risk allocation over the short, medium and long term.

A suite of supporting and enabling policies will be required

As well as direct incentives to enable GGR technologies to commercialise, a wider suite of policies are needed to facilitate their development and deployment in the most effective way.

Most GGR techniques will require innovation and demonstration support before they are ready for commercial deployment. To that end, we are investing £100 million in the research, development and demonstration of greenhouse gas removals across multiple programmes. This includes BEIS's Direct Air Capture and other GGR Innovation Competition, which will support the construction of pilot plants for a range of promising technologies to help them achieve commercial realisation.[10]

Through the government's Strategic Priorities Fund, UK Research and Innovation (UKRI) will invest £31.5 million in five land-based GGR demonstrator projects – involving biochar, enhanced weathering, peatlands, forestry, and perennial bioenergy crops – and a central hub located at the University of Oxford. The hub will lead on coordination across the programme, as well as conducting cross-cutting research on the environmental, economic, social, ethical, and governance implications of GGR approaches.[11]

Robust standards for monitoring, reporting and verification (MRV) of negative emissions will be essential to verify the quantity and permanence of CO_2 removed over the lifecycle of each GGR project. This would provide the basis for calculating net removal of CO_2 from the atmosphere, ensuring that only genuine greenhouse gas removals are rewarded through any future policy mechanisms. In 2021, BEIS established the GGR MRV Task and Finish Group to advise on the work required to advance the development of an MRV policy framework for negative emissions. The final report of the Group has been published alongside this document, and will inform the government's future work in this area.[12]

Availability of CO_2 transport and storage infrastructure will be crucial to facilitate the deployment of large-scale GGR projects such as BECCS and DACCS. The Prime Minister's 10 Point Plan announced a £1 billion CCS Infrastructure Fund and established a commitment to deploy CCUS in a minimum of two industrial clusters by the mid-2020s, and four by 2030 at the latest. We will ensure that GGR policy is coordinated with the development of this vital

[10] BEIS – Direct Air Capture and other Greenhouse Gas Removal technologies competition (link)
[11] UKRI – UK invests over £30m in large-scale greenhouse gas removal (link)
[12] Task and Finish Group on Monitoring, Reporting and Verification of GGRs (2021), Final Report (link)

infrastructure, and deployment of early GGR projects will be considered as part of the Cluster Sequencing process.

As we move forward with deployment, it will be necessary to ensure that GGR technologies do not create new environmental risks when deployed individually and at scale. For instance, feedstock production for BECCS, biochar and wood in construction have potentially significant land requirements which, if mismanaged, could pose risks to biodiversity or misalign with other schemes to reward environmental land management. Impacts on local ecosystems including soil, water and air quality must also be taken into consideration to minimise any potential adverse effects.

The availability of sustainable biomass will be an important determinant of the scalability of certain GGRs, most notably BECCS and biochar. The upcoming Biomass Strategy, due to be published in 2022, will review the amount of sustainable biomass available to the UK and how this resource can be best utilised across the economy to help achieve our net zero target. It will also assess the UK's current biomass sustainability standards, to see where and how we can improve them even further.

Next Steps

In the Net Zero Strategy, the government set out the following commitments on greenhouse gas removals:

- Set the **ambition of deploying at least 5MtCO_2/yr of engineered removals by 2030**, in line with CCC and National Infrastructure Commission assessments.
- Deliver **£100m innovation funding** for Direct Air Capture and other GGRs.
- Develop markets and incentives for investment in greenhouse gas removal methods, by **consulting on our preferred business models** to incentivise early investment in GGRs in 2022.
- Launch a **call for evidence exploring the role of the UK ETS** as a potential long-term market for GGRs.
- Explore options for **regulatory oversight to provide robust monitoring, reporting and verification (MRV)** of GGRs, following the recommendations of the BEIS-led MRV Task & Finish Group involving experts from industry and academia.
- Seek an **amendment to the Climate Change Act** to enable engineered removals to contribute to UK carbon budgets.

The remainder of this document presents a summary of stakeholders' responses to each question in the Call for Evidence.

Summary of Responses to Chapter 1: Greenhouse Gas Removal methods

Chapter overview

The first chapter of the Call for Evidence invited evidence from stakeholders on:

- The role that GGRs should play in reaching the UK's net zero target by 2050.
- The suitability and mix of different GGR technologies.
- Recent evidence in relation to GGR methods, including updated assessments of technological maturity, deployment potential, cost, lifecycle emissions, environmental impacts, and other constraints to deployment.

The Call for Evidence shared Vivid Economics' summary of the latest evidence on the most promising GGR methods (Figure 1).[13] This is reproduced in the Annex to this document. Stakeholders were invited to supply new evidence on the GGR methods listed in Figure 1, as well as novel technologies that were not captured in the Vivid Economics study.

Q1: Do you give permission for your evidence to be shared with third party contractors for the purpose of analysis?

Respondents were invited to give permission for their evidence to be shared with third party contractors for the purpose of analysis. The vast majority of respondents to this question gave permission for their evidence to be shared for this purpose. 46 responses were selected by BEIS for consideration and further assessment in a study undertaken by Element Energy and the UK Centre for Ecology and Hydrology on greenhouse gas removal methods and their potential UK deployment. The findings of the study have been published alongside this Summary of Responses.[14]

The role of GGRs in achieving net zero

Q2: Do you agree that some greenhouse gas removal methods will be required to achieve the UK's net zero target by 2050? What are your views on the suitability and mix of different technologies in supporting the delivery of net zero?

Number of responses: 84

Will GGRs be required to achieve net zero by 2050?

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[13] Vivid Economics (2019), 'Greenhouse Gas Removal (GGR) policy options' (link)
[14] Element Energy and UK Centre for Ecology and Hydrology (2021), 'Greenhouse Gas Removal Methods and Their Potential UK Deployment' (link)

The majority of respondents – including research institutes, academics, think tanks, developers and trade associations – agreed that some level of GGR deployment will be required to achieve net zero. The predominant argument was that despite ambitious action to decarbonise the economy, it is unlikely that emissions will be completely eliminated from the most hard-to-abate sectors such as aviation, agriculture and heavy industry by 2050. As a result, a credible plan to achieve net zero will require GGRs to balance out unavoidable emissions from those industries.

Stakeholders suggested that residual emissions will remain in some parts of the economy due to a variety of technical, economic and societal factors. One innovation centre said that certain behaviours, most notably aviation and meat/dairy consumption, will continue to result in carbon emissions despite deployment of low and zero carbon technologies, and GGRs must therefore be developed to mitigate the need for speculative breakthroughs in technological or societal change in these sectors. Several respondents referred to analysis by major climate institutions such as the IPCC and the CCC as evidence of the need for GGRs, including the CCC's 6th Carbon Budget report.

Although most respondents focused on the role of GGRs in reaching net zero, some pointed out that it might be necessary to go beyond net zero and achieve 'net negative' emissions in the second half of the century in order to reverse some of the effects of historic climate change. In this event, it was argued that greenhouse gas removal would become the main driver of climate action. One academic argued that a narrow focus on the UK's net zero target obscures the longer-term, global role of GGRs in the delivery of the UNFCCC objective to 'prevent dangerous anthropogenic human-induced interference with the climate system'.

However, several respondents did not agree that engineered GGRs should be needed to reach net zero, including a number of environmental NGOs and most members of the public who responded to the Call for Evidence. A key objection was that GGRs are costly and unproven technologies that may not be available at the necessary scale and cost by 2050. A number of stakeholders also raised concerns around land and energy requirements, as well as potential risks to biodiversity.

A number of respondents opposed GGRs on the grounds that there is further scope for reducing emissions in hard-to-abate sectors of the economy. Rather than investing in GGRs, it was argued that there is greater potential to implement decarbonisation options such as battery storage; the use of hydrogen and e-fuels in aviation, HGVs and agricultural machinery; zero-carbon rail; sustainable agricultural practices; and reducing consumer demand for aviation and meat. Some respondents noted that one of the IPCC's four illustrative pathways to achieving 1.5 degrees does not require engineered GGRs such as BECCS, with afforestation the only carbon removal option considered.

A large number of stakeholders – including both sceptics and advocates of GGRs – acknowledged the risk that the development of GGRs could lead to over-reliance on these technologies and discourage meaningful action to reduce emissions. This hazard was commonly described as 'mitigation deterrence'.

There was overwhelming agreement that GGRs should not be treated as a substitute for deep emissions reduction and should not be relied upon to meet climate targets at the expense of cutting emissions. However, most stakeholders believed that GGRs will still be a necessary accompaniment to economy-wide decarbonisation in order to address residual emissions that cannot be abated by other means. A study funded by UKRI found that the risk of mitigation deterrence is “real and substantial”, but nevertheless agreed that there is likely to be a need for GGRs to achieve climate goals.

A number of proposals were put forward to reduce the risk of mitigation deterrence. In particular, several respondents argued that government should prioritise rapid and sustained emissions reduction in order to reduce the need for GGRs in future, while some favoured separate targets for carbon removal and emissions reduction to avoid ‘unplanned substitution’. Along with separate targets, researchers involved in the UKRI-funded study proposed that mitigation deterrence risks should be considered as part of multi-criteria risk assessments for individual GGR projects.

One charity argued that GGRs should have a very limited role as an insurance against ‘unforeseen overshoots’ (such as from climate feedbacks not currently understood). Similarly, another charity that was highly sceptical of the role of GGRs believed that government should only pursue research into engineered GGR technologies in case these prove to be needed in the future.

The suitability and mix of different technologies

Many respondents believed that a broad mix of engineered and nature-based technologies will be necessary to achieve net zero. The main argument was that no single GGR option is likely to deliver the amount of GHG removals required to meet climate goals. As well as the inherent uncertainties around novel technologies and their scalability, it was argued that constraints in supply chains, resource and land availability will limit the deployment potential of any particular GGR option. As such, a ‘portfolio approach’ will be crucial to reduce reliance on any single technology and maximise the chances of achieving GGR at scale.

A number of respondents noted that innovation is likely to change the mix of suitable GGR technologies over time, so government policy should be responsive to new technologies and evidence and avoid premature lock-in to one approach. A few said that near-term policy should favour nature-based solutions that are more affordable and ready to deploy, while expecting there will be a greater role for engineered GGRs in the longer-term as nature-based approaches reach their maximum potential or natural limit due to land availability.

However, several respondents – most notably environmental NGOs and members of the public – believed that nature-based solutions such as afforestation should be preferred over engineered GGR technologies. The main reasons were that nature-based solutions are well-established, affordable, and ready-to-deploy, whilst offering a range of co-benefits alongside climate mitigation such as biodiversity, flood management, water quality, and soil health. In contrast, concerns were raised around the energy-intensive and unproven nature of engineered GGRs such as DACCS and BECCS.

A substantial number of academics, NGOs and members of the public[15] objected specifically to the deployment of BECCS due to a range of concerns such as: impacts on forests, biodiversity, food security and environmental justice in wood pellet sourcing regions; finite supplies of sustainable biomass; and concerns that BECCS could result in increased CO_2 emissions when accounting for the full biomass supply chain, including harvesting, transportation, and the foregone carbon sequestration potential of harvested trees. To a lesser extent, specific concerns were also raised in relation to DACCS – most notably supply chain emissions, heat and energy requirements, and the materials and land area required for the construction of large-scale plants.

In contrast, some respondents emphasised that engineered GGRs can offer important advantages over nature-based solutions. In particular, various GGR developers, academics and charities noted the scalability of DACCS and BECCS as well as the verifiability and permanence of geologically stored CO_2, whereas nature-based solutions such as afforestation and soil carbon sequestration are limited by land availability and may not provide secure long-term storage.

Evidence on GGR methods

Q3: In relation to the GGRs listed in Figure 1, is there new evidence that you can submit in relation to any of the following…

Number of responses: 85

Respondents were invited to provide recent evidence in relation to the greenhouse gas removals described in Figure 1, primarily focusing on engineered methods. A selection of responses were considered as part of the study conducted by Element Energy and the UK Centre for Ecology & Hydrology on greenhouse gas removal methods and their deployment potential in the UK. The research project, which has been published alongside this Summary of Responses, presents the latest evidence on GGRs, assessing their role in reaching net zero as well as their scale-up potential, costs, and barriers to deployment.

The following sections summarise stakeholder responses to each part of Question 3.

(i) Technology readiness levels

Respondents generally considered that technology readiness levels (TRL) for most GGRs are higher than estimated in the Vivid Economics report. Only a small number of technologies were estimated as being below TRL 6. A common theme was that technology developers tended to

[15] In addition to responses from individual organisations and members of the public, the government received a number of coordinated submissions expressing concern over the viability of BECCS as a GGR method. This included a joint statement from 21 NGOs, a separate joint submission from 4 NGOs, a joint statement from 87 scientists and economists, and an online campaign supported by 557 members of the public.

provide higher TRLs than charities or potential end-users. Higher TRLs were usually justified by reference to demonstration projects being conducted outside the UK.

Eight respondents provided information relevant to DACCS, most of whom were technology developers. They usually identified the technology as being TRL 6 or 7, though some specific types were estimated as being at an earlier stage. Those that gave evidence on biochar – including academics and developers – all identified it as being TRL 6 or 7. Enhanced weathering was generally considered to be TRL 4, though one developer estimated the TRL at 7 with reference to enhanced weathering schemes in the Netherlands. One respondent provided evidence that carbon negative concrete is already at (or very close to) full commercialisation, and estimated a TRL of 9.

(ii) Scale-up potential

A number of respondents highlighted the inherent uncertainty of estimates of GGR scale-up potential due to the nascent status of the sector. Overall, several respondents – including academics, developers and trade associations – suggested that the deployment estimates published in the Vivid Economics report were reasonable on the basis of the evidence currently available. Multiple respondents also cited the scale-up estimates included in the CCC's Carbon Budget 6 advice.

A few stakeholders, mainly developers, believed that DACCS and Power BECCS could be deployed at megatonne scale in the UK over the next decade. Some stakeholders discussed the deployment potential of BECCS outside the power sector, including BECCS for the production of biohydrogen and low-carbon liquid fuels, energy-from-waste, as well as syngas and biochar production from waste. They also pointed out that different BECCS technologies could enable other hard-to-abate sectors to decarbonise, including industry through cement and lime production and aviation through production of biofuels. A few respondents from industry highlighted that the Vivid Economics report refers only to solid sorbent DACCS and does not directly consider liquid solvent methods.

On the other hand, submissions from multiple academics, NGOs and think tanks suggested there is limited negative emissions potential from BECCS due to issues around the biomass supply chain and biomass carbon accounting. Some trade associations and charities noted that the Vivid Economics report did not discuss the potential for anaerobic digestion, which could play a role both in BECCS and soil carbon sequestration.

A few respondents highlighted the potential for earlier deployment of land-based solutions. In particular:

- A few stakeholders discussed the potential to scale-up biochar production in the UK, particularly if a wide range of timber by-products are used (including those from coppicing of new plantings).
- One university provided contextual information on the potential associated with repurposing existing quarry fines production for carbonation and enhanced rock weathering.

- A charity highlighted the removal potential associated with saltmarsh creation and restoration.

While most evidence focused on deployment potential in the UK, some respondents provided information on the global scale-up potential of GGR solutions. A few stakeholders cited evidence suggesting that GGRs will be required to limit global warming to 1.5-2°C. However, these respondents also highlighted the uncertainty underlying global estimates of GGR deployment to meet Paris Agreement targets.

Across different GGR solutions, one research institute suggested that between 7 and 70 $GtCO_2$ of annual removals could be needed to meet the Paris Agreement targets, based on analysis of different evidence sources. DACCS, BECCS, soil carbon storage and afforestation were identified as the solutions likely to make the largest contribution. A few respondents also highlighted the global potential for scaling up biochar.

(iii) Costs per tonne of CO_2 removed

Most cost information supplied by stakeholders related to BECCS, biochar, carbon-negative concrete, DACCS, and enhanced weathering. While a number of respondents provided a cost per tonne estimate of the CO_2 removal process, few stakeholders provided clarity on the period they were referring to. Furthermore, it was not clear in many cases whether respondents were including transport and storage costs in their estimates.

Most submissions that provided a £/tonne estimate for BECCS aligned with the Vivid Economics report (£80-230/tonne).[16] This range was dependent upon the technology, region and feedstock used. A small number of responses, including a joint submission from a group of scientists and economists, argued that the carbon capture potential of BECCS has historically been overestimated - resulting in under-estimates of costs per tonne of CO_2 removed.

There was large uncertainty around the costs of DACCS, with most respondents providing figures between $100 and $1,000/tonne. DACCS developers tended to provide lower estimates, suggesting deployment could cost less than £300/tonne by 2030. Overall, the majority of responses which provided a £/tonne figure suggested the upper end of the range outlined in Vivid Economics report (£160-470) is too high. Some respondents also noted differences in costs between liquid-based DAC and solid sorbent DAC technologies.

For biochar, total costs approaching the upper end of the Vivid Economics estimate (£14-130/tonne) were reported by a developer and a research institute. However, it was also suggested that the costs of biochar application could be negative (i.e. result in profit) when accounting for revenue streams such as energy generation.

Enhanced weathering operational costs were estimated to be up to £80/tonne for 'ultrabasic' rocks and up to £350/tonne for 'basic' rocks, falling within the range outlined in the Vivid Economics report (£39-390/tonne). A developer based in the Netherlands believed that costs

[16] Vivid Economics (2019), 'Greenhouse Gas Removal (GGR) policy options'. Cost figures refer to 'Table 2: Indicative costs of GGR', page 14.

per tonne could reach approximately €40/tonne CO_2 removed, depending on the type of olivine used. A group of academics estimated production costs for enhanced weathering (excluding transport) at $5-25/tonne, noting that the variable cost of electricity to operate machinery would be a key factor in determining where costs would fall in this range.

In relation to carbon-negative concrete, a trade association estimated that BECCUS in cement manufacture could reach £60/tonne by 2050.

Several stakeholders provided information relating to specific cost components. For instance, some respondents suggested that energy requirements and costs for DACCS could be reduced significantly if coupled with 'waste heat' from nuclear. Transport costs were also identified as an important variable that could affect lifecycle costs of CO_2 removal.

(iv) Constraints to deployment

Stakeholders provided evidence on barriers to specific GGRs as well as general constraints to deployment which apply across a range of solutions.

Many respondents cited a lack of policy incentives as the key constraint hindering deployment of GGRs in the UK, particularly engineered solutions such as DACCS and BECCS. It was widely suggested that without a price or reward for negative emissions, deployment may not be financially viable. A few respondents also mentioned a lack of policy incentives for switching to the low carbon fuels produced by BECCS (e.g. hydrogen, biogas, biomethane and biofuels).

Aside from the lack of an established market or policy incentives for negative emissions, resulting in uncertain revenues for technology developers, stakeholders highlighted other cost barriers such as high capital requirements, long payback times, and ongoing operational costs (e.g. CO_2 transport and storage, energy, solvent costs).

A mix of academics, developers, NGOs, think tanks, charities, and members of the public identified high resource requirements as the main constraint to GGR deployment and scalability. These concerns focused primarily on biomass, land and energy requirements:

- Availability of sustainable biomass was widely identified as a fundamental constraint to BECCS deployment, in relation to both domestic supply chains and imported feedstocks.
- Land requirements were highlighted as a concern for scaling GGRs such as BECCS, biochar, enhanced weathering and DACCS. Some respondents highlighted the risk of competition for land use, both between different GGR solutions (e.g. between BECCS and afforestation) and with other uses such as food production. However, some stakeholders highlighted the potential to use land simultaneously for different uses (e.g. agroforestry).
- Large energy requirements were specifically raised in relation to DACCS, which requires substantial electricity and heat energy to extract CO_2 from air and regenerate solvents. However, some respondents suggested that this requirement could in part be satisfied by co-locating DACCS with sources of waste heat.

- A few respondents highlighted additional resource requirements such as water (for BECCS and DACCS), solvents (DACCS), and nutrients (soil carbon sequestration).

Many academics, NGOs, developers and trade associations highlighted readiness of CO_2 transport and storage infrastructure as an important barrier to engineered removals. Key concerns included availability of storage facilities in the timescales needed for early deployment (e.g. the late 2020s) and a lack of organisational coordination to develop infrastructure. A few developers feared that the immaturity of transport infrastructure and delays in appraising suitable storage sites might affect the ability to convert and deploy small-scale distributed BECCS plants, which might be further away from existing storage facilities.

Several respondents noted the low technology readiness levels of engineered GGR technologies, and advocated further research to understand how best to deploy these techniques efficiently and effectively. Environmental risks were also considered as a barrier to deployment by a number of researchers, NGOs and charities, with particular concern around the impact of BECCS and land-based solutions on biodiversity and soil quality.

A few stakeholders identified public acceptability challenges facing engineered GGRs as a barrier to adoption. Some also discussed behavioural barriers to adoption of GGR practices among farmers, including low awareness of the benefits of soil carbon.

(v) Ability to verify the quantity and permanence of removals

Robust monitoring, reporting and verification (MRV) procedures were considered to be essential to underpin effective deployment of GGRs. It was widely recognised that each GGR method presents unique MRV challenges to a greater or lesser extent, and a number of respondents suggested that different GGRs could warrant specific MRV approaches.

- A small number of stakeholders, including a project developer, highlighted uncertainty in the verification of enhanced weathering. A key reason was that the mineralisation process takes many years, preventing real-time measurement.

- The uncertainty in measuring soil carbon sequestration was recognised. Two respondents described direct and indirect methods which could be used to verify soil carbon sequestration, including soil sampling and modelling techniques for larger projects.

- Some respondents acknowledged the ongoing disparity in views around the ability to successfully measure and verify biochar removals, as a result of contrasting assumptions.

- There were differing views on the difficulty of verification for DACCS. While developers suggested that CO_2 removal is easily measurable, some organisations expressed concern that current methods of verification were either difficult or immature.

Several respondents stressed that assessing supply chain emissions is essential for ensuring the integrity of removals. A few respondents, including an international think tank, claimed that supply chain emissions are not fully factored into calculations of net negativity of GGRs such as BECCS and DACCS. One respondent suggested that since DACCS does not currently fall under any international accounting rules, it would not satisfy the necessary criteria for inclusion within Nationally Determined Contributions under the Paris Agreement.

A public body suggested that the monitoring and verification of greenhouse gas removals could be added to the activities currently regulated under the Environmental Permitting Regulations.

One academic cited evidence that using GGRs to remove one tonne CO_2 from the atmosphere leads to a net effect of less than one tonne CO_2 removed, due to dynamic interactions with the global carbon cycle. As a result, they argued that a discount factor should be applied in any rewarding mechanism for negative emissions.

(vi) Lifecycle emissions in the UK

Little quantitative information on lifecycle emissions was provided by respondents, although several GGR developers provided assurances that their specific technology delivers net negative emissions over the full lifecycle. Only two stakeholders provided evidence on quantified lifecycle emissions – a BECCS developer and a university conducting research on enhanced rock weathering.

However, a number of stakeholders, including NGOs and academics, believed that the accounting methodologies used to justify BECCS are flawed. These respondents expressed concern that BECCS does not deliver negative emissions once foregone sequestration from harvested trees is taken into consideration, along with supply chain emissions from the harvesting, transport and processing of biomass.

(vii) Wider environmental impacts and risks

A broad range of evidence on environmental impacts and risks was provided.

Several respondents highlighted concerns around the environmental risks of deploying BECCS. Specific concerns related to high land and water requirements (and potential trade-offs with food production); sustainability of biomass feedstocks; impacts on biodiversity; conversion of large areas of land to monoculture tree planting; and carbon debt from tree planting, with some respondents stating that it can take a minimum of 40 years for forest regrowth to replace the emissions burned in bioenergy generation. Several respondents highlighted that significant levels of imported biomass would be required to reach the scale of BECCS deployment outlined in the Vivid Economics report.

A number of respondents cautioned that biochar and enhanced weathering could lead to irreversible impacts on soil and water. It was also highlighted that if these processes offer no demonstrable benefits to soil quality, they may require regulation as waste products under the Environmental Permitting Regulations. A few environmental groups and academics suggested that enhanced weathering could cause soil contamination or damage to ecosystems.

However, one academic and biochar business owner argued that the risk to water quality highlighted in the Vivid Economics report refers to outdated evidence, and that the application of biochar has been since shown to decrease ‘fertiliser run off’ in soil application and may therefore enhance water quality.

Some DACCS developers argued that the technology offers significant advantages over other engineered GGRs such as BECCS due to its lower land requirements and limited impact on the surrounding environment. However, a number of academics, think tanks, and members of the public noted that DACCS will require low-carbon or zero-carbon sources of heat and electricity in order to deliver negative emissions over the entire life cycle. Some also raised environmental risks associated with the production and use of chemical sorbents at large scale.

One respondent highlighted that BECCS and DACCS do not capture other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O).

Q4: Is there any evidence you would like to submit in relation to other nascent GGR methods not outlined in Figure 1?

Number of responses: 40

Stakeholders described a wide range of technologies and approaches in response to this question. These methods can be considered to fall into three categories:

1. Novel GGR methods that were not identified explicitly in the Call for Evidence document
2. Variants of GGR methods outlined in Figure 1 – such as the use of hybrid technologies, novel capture mechanisms, and novel materials or feedstocks
3. Technologies that do not remove greenhouse gases from the atmosphere and are therefore outside of the scope of the Call for Evidence

Quantitative evidence was often limited, including information on costs, removal potential, and input requirements. However, several technology developers provided useful data and details of the potential benefits of their technologies.

Novel GGR methods

Multiple respondents described, in varying levels of detail, new GGR methods that were not directly addressed in the Call for Evidence document. The methods proposed were at varying levels of maturity – from early-stage concepts to technologies that are being researched, tested or deployed at small scale. This included:

- Anaerobic Digestion plants optimised for greenhouse gas removal
- Thermal cracking technology to convert waste into clean syngas and biochar
- Steam reformation of biogas to produce hydrogen and carbon for capture
- Iron salt aerosols for methane removal
- Microbial gas fermentation
- Ocean fertilisation

- Ocean alkalisation/liming
- Carbon removal through electrolysis of seawater
- Transport of biomass or chilled CO_2-concentrated seawater to deep oceans
- Algae bioreactors to capture CO_2

A number of respondents highlighted the potential environmental risks of adding substances to the ocean, and the importance of further research to ensure that these impacts are fully understood before proceeding with deployment. It was also noted that ocean-based GGR methods are constrained by the London Convention/London Protocol.

Variants of GGRs outlined in Figure 1

Most of the GGR methods proposed in response to this question can be considered variants of the GGRs described in the Call for Evidence. These included:

- Regenerative liquid-based approaches to Direct Air Capture
- The use of artificially produced materials, such as lime, for enhanced weathering
- Alkaline material carbonation using industrial waste such as steel slag
- Accelerated mineralisation, using high pressures and temperatures to further accelerate the weathering of rock material (compared to conventional enhanced weathering)
- The use of non-woody biomass in construction e.g. straw wall panels, fibre-based insulation etc.
- The conversion of biomass into bioplastics and other long-lived bio-based products to provide a long-term carbon store
- Habitat restoration other than peatlands, such as saltmarshes
- Alternative nature-based approaches such as agroforestry, hedgerows, peat soil management, and perennial energy crops

The definition of BECCS in the Call for Evidence was considered ‘narrow’ by multiple respondents, who described a variety of specific applications such as:

- CO_2 capture on biohydrogen production (from gasification of biomass)
- CO_2 capture on biofuel production (for example from gasification of waste and Fischer-Tropsch synthesis)
- CO_2 capture on biomethanol/ethanol production
- CO_2 capture on bioenergy-fuelled industrial processes (such as glass, cement and lime production)
- CO_2 capture on energy-from-waste
- CO_2 capture on anaerobic digestion (some respondents noted that anaerobic digestion of biowaste can produce biogas that can subsequently be used as a fuel for BECCS)

- Biomass Carbon Removal and Storage (BiCRS) – biomass carbon removal without energy production

Respondents proposed various uses for the energy produced by BECCS, including heat for homes and lime kilns. One developer described a hybrid technology which uses BECCS for the production of biochar, heat and power.

Technologies outside of scope

Proposals in this category generally involved technologies that would mitigate emissions from industrial processes and/or utilise captured carbon, but not remove greenhouse gases from the atmosphere; for example, using captured CO_2 to produce sustainable fuels and fertilisers. A number of academics and charities discussed agricultural and land management practices with the potential to reduce emissions rather than capture carbon. A couple of respondents proposed geoengineering methods such as solar radiation management.

Summary of Responses to Chapter 2: Incentivising investment in GGRs

Chapter overview

The second chapter of the Call for Evidence explored the role of government in incentivising the development and deployment of GGRs. It considered and invited views on:

- Market barriers to investment in GGRs, building on the types of market barrier identified in the Vivid Economics report.
- Principles to guide government intervention and future policy on GGRs.
- Policy options for incentivising investment in GGRs, drawing on the policies discussed in the Vivid Economics report.
- Wider considerations for policy design – such as technology neutrality, interaction with policy in other sectors, international initiatives on GGR, and the changing role of government over time.

Barriers to GGR deployment

Q5: What do you consider to be the main barriers to the development and deployment of GGRs?

Number of responses: 67

There was broad agreement among stakeholders that the Vivid Economics report identified the main types of market barrier facing the GGRs sector: financial barriers; accounting barriers; regulatory and infrastructure barriers; innovation and demonstration barriers; and environmental risks. The lack of financial incentives and robust carbon accounting protocols for negative emissions were generally considered to be the most important barriers for government to address.

Financial barriers

A majority of respondents cited financial barriers to the development and deployment of GGRs, with many considering this to be main market barrier. It was argued that there are insufficient incentives for businesses to invest in engineered GGRs due to the absence of a price or reward for negative emissions, coupled with large upfront capital costs and high long-term operating costs. Some stakeholders noted that the lack of reward for negative emissions is both a supply-side barrier and demand-side barrier: developers require stable long-term revenue streams to secure investment and bring GGRs to market, while emitters in hard-to-abate sectors require a financial incentive and a clear route to procure engineered removals to offset their emissions. Several respondents pointed to a lack of a functioning, liquid market for carbon removals.

Accounting barriers

Accounting challenges were the second most frequently-cited barrier to deployment. Stakeholders noted difficulties around the monitoring, reporting and verification (MRV) of negative emissions, and associated uncertainty around the quantity of CO_2 removed by various methods and the permanence of storage. Several respondents discussed the negative impact of these uncertainties on the perceived legitimacy of removals. Some respondents believed that MRV poses a particular challenge for soil-based options.

Infrastructure barriers

A number of respondents highlighted the lack of CO_2 transport and storage infrastructure as a barrier to deploying engineered projects such as BECCS and DACCS. One stakeholder noted the particular challenge of ensuring that transport and storage networks are available for projects located outside of planned CCUS clusters.

Innovation and demonstration barriers

Some respondents noted that further innovation and demonstration support will be required for immature GGR methods before they are ready for deployment at scale. It was recognised that GGR technologies are at different stages of technology readiness and early-stage methods may require bespoke support to become commercially viable. Biochar was often cited as a method that would benefit from further research and demonstration. However, a handful of developers and energy providers emphasised that financial considerations, rather than technological barriers, are the main impediment to commercialisation of BECCS and DACCS.

Environmental barriers

Various respondents identified environmental risks as one of the main barriers to GGR deployment. The most common environmental concerns included: competition for finite land resources, risks to biodiversity, unknown impacts on soil and marine ecosystems, and the sustainability of biomass feedstocks.

Other barriers to deployment

While responses generally focused on the deployment barriers described in the Call for Evidence, a number of stakeholders identified additional barriers to the development and deployment of GGRs.

Some respondents believed that GGR deployment could be hindered by lack of joined up policy-making, and encouraged government to set out a long-term vision for GGRs as part of its wider plan for net zero. Furthermore, a few respondents felt that negative public perceptions of GGRs posed a significant barrier. These argued that it would be necessary to ensure GGRs are not used as a substitute for emissions reduction in order for GGRs to gain public acceptance and a social licence to operate.

Other barriers mentioned by one or two respondents included:

- Regulatory barriers, such as the London Protocol (which restricts deployment of ocean based methods such as Ocean Iron Fertilisation) and Environmental Permitting Regulations (which may impact application of biochar and enhanced weathering).
- Academic barriers, particularly in relation to incomplete or conflicting evidence around the viability of specific methods.
- Lack of awareness or antipathy to new technologies, particularly for relatively new or less well-known GGR methods such as biochar, enhanced weathering and anaerobic digestion.
- Behavioural barriers among farmers and land managers – including low awareness of the importance of soil organic matter, concerns around cost-effectiveness, and conflicting messages around the potential of different on-farm interventions and technologies.

Principles for government intervention

Q6: What principles would you like to see included in a framework for incentivisation of greenhouse gas removals?

Number of responses: 66

Respondents broadly agreed with the six principles outlined in the Call for Evidence, as discussed below. The most frequently cited of these was the principle of ensuring that removals are verifiable and quantifiable, which was endorsed by almost half of respondents.

Making sure removals are verifiable and quantifiable

A large number of stakeholders agreed that greenhouse gas removals should be verifiable and quantifiable. They highlighted the importance of accurate carbon accounting and effective MRV to instil confidence in the legitimacy and integrity of removals. Several respondents also recommended that permanence should be a key principle in any policy framework for GGRs – ensuring that policy incentivises methods that provide secure negative emissions over the long-term and accounts for the risk of reversibility. A few stakeholders argued that incentives should only be available for GGRs that deliver greenhouse gas removal based on a full lifecycle assessment.

Instilling confidence in investors

The principle of instilling confidence in investors was widely supported, with some respondents from industry and academia highlighting this as one of the most important principles for government policy. A number of stakeholders argued that without business models and supporting policies that give investors the confidence to invest private capital, a negative emissions sector will struggle to deploy at scale.

Ensuring value for money

Many respondents believed that value for money and cost-effectiveness should be important principles for GGR policy. However, some stakeholders (most notably from industry) argued that flexibility would be required for early projects which may not meet standard value-for-money criteria due to the high levels of upfront investment required, but which will enable cost reductions and economies of scale to be realised in the longer-term.

Being technology neutral

Technology neutrality was identified as a key principle by a large number of respondents. Advocates of this principle highlighted the risks of prematurely ‘picking winners’ given the early stage of GGR technologies and the pace of innovation in this field. However, a significant number of stakeholders from industry felt that while technology-neutrality should be a long-term goal of GGR policy – with different technologies competing in the market – this would be unsuitable for early projects which may require bespoke support.

Attracting innovation

Only a small number of respondents addressed this principle directly, though the ability to fund research and innovation was identified by one developer as the most important principle.

Making a wider economic contribution

A few stakeholders highlighted the potential for the emerging negative emissions sector to support green jobs in the UK and revitalise industrial regions.

Additional principles

A number of principles not mentioned in the Call for Evidence document were proposed for inclusion in a GGRs policy framework. The most common suggestions were:

- **Avoiding mitigation deterrence:** Several respondents argued that incentives for GGRs must not deter from delivering ambitious emissions reductions in other sectors. Some believed that GGR incentives should not make GGRs cheaper or more attractive than developing or adopting other low-carbon technologies. One stakeholder stressed the importance of avoiding any perverse incentives to emit greenhouse gases in order to benefit from incentive payments to then remove them.
- **Minimising environmental risks:** Several respondents advised that safeguards must be in place to ensure that GGR deployment is sustainable, avoids adverse environmental effects, and complements existing policy such as the 25 Year Environment Plan and Sustainable Development Goals. Maximising the potential co-benefits of GGRs, such as increased biodiversity, was also mentioned as an important consideration for policy.
- **Social fairness:** Some respondents argued that any incentives for GGRs must consider issues of social justice and support a just transition to net zero. The main proposals for incorporating social fairness within GGRs policy included: adopting the ‘polluter pays’ principle; ensuring that direct and indirect costs of deployment are distributed fairly;

ensuring that policies are implemented with full engagement of local communities and that each GGR project possesses a social licence to operate; and carrying out public impact assessments before GGRs are deployed at scale to ensure that any impacts do not disproportionately affect vulnerable communities.

A couple of respondents highlighted the importance of international leadership from the UK on the development and deployment of greenhouse gas removals. Some also recommended that policy should consider the scalability of different GGR techniques, with interventions targeted at methods that have potential to remove CO_2 on a large scale.

Other suggested principles included: transparency around the implications of GGR deployment and responsiveness to societal concerns; establishing confidence by providing clear and strong policy signals; acknowledging synergies between GGRs and other low-carbon technologies such as nuclear, hydrogen, and production of synthetic fuels; flexibility and responsiveness to learning and innovation; and embedding circular economy principles within the GGR policy framework.

The role of government in incentivising GGRs

Q7: What specific policy mechanisms could the government consider to incentivise (a) innovation and (b) initial deployment? Could any of the policy options outlined above be designed in a way that stimulates investment in innovation, including pilots and demonstrators for less mature technologies?
Number of responses: 52

Q8: How could government best contribute to establishing optimum market conditions for GGRs to be developed and deployed at a large scale?
Number of responses: 55

Q9: How might the role of government change over time to bring GGR technologies to market and encourage their deployment up to 2050?
Number of responses: 32

The responses to these questions explored the role of government in the development and deployment of GGR technologies; approaches to establishing and optimising market conditions; and the changing nature of government intervention in this sector over time.

A large majority of respondents believed that policy support will be needed to encourage the development and rollout of GGRs. While stakeholders expressed a range of views in regard to the specific policy mechanisms required, there was a broad consensus around the role of government in supporting technologies from the innovation stage through to commercial deployment. Furthermore, a common theme was that different policy mechanisms may be appropriate as the sector matures over time.

A small number of stakeholders were opposed to GGR technologies and believed that government should not play any role in their development and deployment. The main reasons cited were the high cost of GGR technologies, the fact that they have not yet been proven at scale, the risk of delaying action on emissions reduction, and the amount of resources required (such as land, biomass, and energy).

The following sections summarise stakeholder views on the role of government in relation to (i) research and innovation, (ii) deployment, and (iii) policies required to grow and sustain an effective market for carbon removals.

GGR research and innovation

Many respondents believed that research and innovation support will be required to develop novel GGRs. Grant funding, direct payments and loans were the policy instruments most commonly recommended to incentivise the research, development and demonstration of new technologies. This ranged from grants for early 'proof of concept' studies, to funding for pilots and demonstration projects for technologies at a later stage of development.

A number of stakeholders noted that the UK government is already investing in the research, development and demonstration of GGRs – including through the UKRI Strategic Priorities Fund 'Greenhouse Gas Removal Demonstrators Programme' and BEIS's 'Direct Air Capture and other Greenhouse Gas Removals competition'. The BEIS competition was highlighted as a positive example of competition-based innovation support, while its aim to develop a portfolio of large-scale GGR approaches was also welcomed. One developer noted that the competition was restricted to technologies which had already achieved TRL 4, and suggested that consideration could be given to opening up a separate lot or scheme for technologies at an earlier stage of maturity.

Aside from grant funding and loans, a small number of stakeholders recommended R&D tax credits and/or match funding as options to encourage innovation. One developer highlighted the need to balance public support with a requirement for private sector match funding in order to ensure continued involvement from technology developers to secure a return on investment. A few stakeholders also mentioned the value of industry/academia partnerships, with some proposing that innovation policy should encourage collaboration with UK research institutes or universities.

Of those who expressed a view, the vast majority of respondents indicated that bespoke support will be required for innovation, compared to wider policy incentives to enable commercial deployment. However, one academic consortium believed that investable business models could also encourage investors and developers to put their own resources into innovation to maximise the return on their product. Another academic suggested that revenues from commercial deployment could be invested back into R&D for less mature technologies.

Despite broad agreement on the importance of targeted innovation policies, a handful of respondents – including energy consultants, trade associations, and public sector organisations – stated that visibility of long-term policy support and a clear route to market will be crucial to attract investment in innovation. It was argued that without a clear pathway to take new technologies from innovation through to commercial deployment, with a stable source of revenue, some innovative solutions may not get the resources required to progress beyond initial studies.

Two research institutes emphasised the importance of a portfolio approach which fosters continual innovation, learning, and the testing of new approaches given the rapid pace of innovation in this field. As the evidence on GGR methods is expected to change continually over the coming decades, it was suggested that government should keep a dynamic portfolio of options under review and avoid premature lock-in to particular technologies.

Deployment and the changing role of government

Among respondents who agreed that GGRs should form part of the UK's net zero pathway, there was a strong consensus that government should play an active role in promoting their deployment.

Overall, the policy mechanisms discussed in the Call for Evidence document were considered to encompass the main approaches available to government to stimulate investment in GGRs. There were varying levels of support for each policy mechanism, with some respondents indicating a clear preference for a specific policy while others were agnostic between several options. Furthermore, it was often noted that the choice of policy mechanism should be appropriate to the maturity of technologies, and that some policies will be more applicable to early-stage projects while others are better suited to longer-term deployment.

Most respondents believed that targeted government support will be required in the near-term to enable initial GGR projects to deploy. The absence of a price signal and market demand for negative emissions was commonly identified as the main market barrier facing GGRs. A wide range of stakeholders therefore argued that there is a need for government action to establish a price mechanism and revenue certainty, particularly for FOAK and early projects, to ensure that these technologies are deployed. As well as reducing financial risk to the private sector, it was also suggested that near-term policy action will be crucial to improve understanding of deploying GGR technologies, enabling early operational experience and learning-by-doing ahead of large-scale rollout.

However, there was a common theme across a broad range of stakeholders – including developers, research institutes, academics, and trade associations – that the role of government should change over time. Around a third of respondents suggested that while bespoke policy mechanisms will be required to support early projects to deploy (such as government-backed service contracts), there should be a transition in the longer-term towards market-based mechanisms to drive the deployment of GGRs at scale once these techniques have become more commercially established. At this point, it was expected that public funding of GGR projects would recede, with the role of government shifting from bespoke support to regulatory oversight of the market framework.

Stakeholders expressed different views on the most appropriate market solution to drive investment in GGR technologies in the longer-term. The inclusion of negative emissions in the UK ETS or the introduction of a GGR obligation scheme were commonly cited as options which could create a consistent demand for negative emissions, while a smaller number of stakeholders recommended tax-based incentives. Several respondents said that visibility of the long-term policy mechanism, and an understanding of how the market will develop over time, will be crucial for developers to support long-term planning. On the other hand, many of the same stakeholders cautioned against implementing a self-sufficient market structure too quickly, on the basis that a lack of 'liquidity' and consistent customer demand in the early stages of deployment may result in large fluctuations in price and lower investor appetite.

Stakeholders provided detailed comments on the specific policy mechanisms set out in the Call for Evidence. These are summarised in subsequent sections of this document. In addition to those policies, however, stakeholders proposed a variety of other policy options to attract investment in GGRs. This covered a range of general and technology-specific proposals, such as:

- Tradeable put options – allowing developers to secure a guaranteed minimum price for negative emissions, while retaining flexibility to sell at a higher price on the market.
- Tradeable Energy Quotas (TEQs) – a form of economy-wide personal carbon trading where individuals must surrender carbon units (allowances) when fuel or electrical energy is purchased, and a market enables carbon units to be bought and sold within the limits set by the Carbon Budget. Two proponents suggested that a TEQs system could help to stimulate negative emissions technology, as well as emissions reductions across society.
- Embedding timber requirements into building regulations to promote the use of wood in construction.
- A Wetland Carbon Code to provide a framework for carbon removal from saltmarsh and blue carbon projects.
- A Soil Carbon Code to encourage land management practices which sequester carbon from soils, following feasibility studies and pilots.
- Access to funding for nature-based and land-based solutions via the government's environmental land management schemes.
- Policies to address specific barriers to the deployment of enhanced rock weathering, such as a lack of comprehensive production statistics, disincentives caused by the Aggregate Levy, and the need to ensure suitability for food production.

One developer advocated a phased approach to commercialisation through the initial roll-out of smaller, less capital intensive projects, rather than a strategy of rapid scaling. It argued that this would de-risk viable technologies and more effectively draw in private funding.

Optimising GGR market conditions

As outlined above, it was widely argued that a market-based framework for GGRs would be suitable in the longer-term, once technologies mature and become deliverable at scale. A number of stakeholders across industry, academia, and the third sector believed that this could best be achieved through a robust, progressive system of carbon pricing, potentially through the UK ETS or a carbon tax. Assuming a sufficient rise in the cost of carbon, it was argued that this could encourage private investment in removals by allowing emitting industries to purchase negative emissions in place of paying the carbon price. One research institute noted that emitters would face three compliance choices: abate remaining emissions, purchase negative emissions, or pay the carbon price.

However, while some stakeholders suggested that robust carbon pricing will be the most important measure to achieve an effective market for GGRs, one carbon finance consultancy was doubtful whether a high carbon price would be sufficient to incentivise high-cost GGRs such as DACCS and BECCS, even when these technologies become more mature.

Beyond near-term support for the sector and visibility of a long-term market mechanism, stakeholders identified a variety of broader policies that could help to optimise market conditions for GGRs. In particular, many respondents highlighted the importance of standardised carbon accounting in order to ensure there is a consistent and accurate approach to measuring and verifying carbon removed from the atmosphere. It was argued that this would create confidence around GGR claims, ensure that policies are linked to genuine climate benefits, and avoid the risk of double-counting.

Numerous respondents across industry, academia and the public sector recommended a similar set of actions that government could take to signal its long-term support for the sector. These included: publishing a Greenhouse Gas Removal Strategy; setting clear targets and milestones for GGR deployment; providing clarity on how GGR incentives will interact with business models under development for CCUS; a clear statement of risk allocation to increase confidence in investment security for investors; and building public support for engineered GGRs and their role in achieving net zero.

A smaller number of stakeholders proposed the following:

- Separate targets for emissions reductions and emissions removals to ensure that the rollout of GGRs does not delay or disincentivise efforts to reduce emissions.
- Enabling the stacking of benefits and revenue streams, particularly for nature-based projects which provide a range of co-benefits beyond carbon removal such as biodiversity gain and flood protection. This would ensure that each benefit type is properly rewarded, helping to maximise the commercial viability of these projects.
- Developing the knowledge, skills and supply chains necessary to deliver GGR innovations, and embedding GGR priorities within the foundational industries for different technologies (such as the bioenergy sector).
- Implementing the recommendations of the Taskforce on Scaling Voluntary Carbon Markets, to ensure there are robust standards in place as well as appropriate governance of those who sell and purchase carbon removals on voluntary markets.
- Creation of a regulatory body to establish principles and frameworks for carbon accounting and oversee the deployment of GGRs in the UK.

- An international standardised framework for rewarding negative emissions, to be negotiated and adopted by Parties to the Paris Agreement.

One research institute advised government against seeking to optimise market conditions “until there is some real deployed capacity to optimise”, adding that this would likely require state-funded early deployment. Another academic opposed the marketisation of GGRs entirely, on the grounds that a market-driven approach cannot deliver the coordinated international effort required to deploy GGRs effectively and on the scale required to meet global climate objectives. Instead, it was argued that government should establish a ‘UK Institute of GGR’ to drive forward research and development, and work with international partners to establish a supra-national agency responsible for delivering a coordinated global GGR programme.

Considerations for policy design

Q10: What factors should be considered when assessing the suitability of different policy options for businesses?

Number of responses: 31

Stakeholders identified a range of commercial and other considerations that should be taken into account when assessing policy options for GGR. Responses largely focused on the importance of long-term policy stability and certainty of revenue to boost investor confidence, though a variety of other issues were discussed such as interaction with wider policies, environmental sustainability, and the potential economic benefits of the GGRs sector.

Most respondents highlighted in some form the importance of policy stability, clarity, and certainty in order to instil investor confidence and provide assurances around return on investment. Specific considerations included: revenue certainty over the project lifetime; reduced financial risk for businesses; protection from price fluctuation in GGR markets; minimising the risk of policy changes; and clarity on pathways and timescales for deployment. The need for financial support for initial projects was raised by some stakeholders, particularly in relation to new technologies with high upfront capital costs.

Ensuring that policy incentivises a range of technologies was identified as a key design consideration by many respondents. Stakeholders noted the importance of ensuring that support is available for technologies at varying TRL levels, providing bespoke support where necessary. A few respondents said that policy should be designed to support businesses of different sizes – from large companies to new start-ups.

A number of stakeholders discussed the need to ensure that GGR policies are compatible with policies in other sectors, such as emerging CCUS business models and existing policies in the renewable energy and waste management sectors. Respondents also raised the importance of access to vital enabling infrastructure, including CO_2 transport and storage infrastructure and hydrogen networks.

Other policy considerations proposed by multiple respondents included: feasibility and simplicity to ensure that any administrative burden is minimised and the policy can be implemented in a timely fashion; potential risks or benefits to the environment and the wellbeing of communities, both locally and globally; potential for the creation of green jobs and promoting a just transition to a low carbon economy; fair cost sharing; transparency in the provision of policy support; and consideration of how short-term policy mechanisms may allow a gradual transition to a market-based approach.

A couple of stakeholders noted issues around international competitiveness. In particular, it was argued that GGR policy should position British companies to take advantage of an emerging global market and avoid incentivising the development of new technologies which are then transferred to other countries for manufacture.

Other considerations put forward by individual stakeholders included: avoiding the risk of carbon leakage; ensuring that policy incentives are developed with the input of industry; and promoting permanence and scalability.

Q11: Are there any existing business models in other sectors – such as power, industry, transport or land use – that could complement new schemes to incentivise GGRs

Number of responses: 29

In response to this question, stakeholders described a variety of existing policies that could support the deployment of GGRs or provide a model for future policy interventions.

The most commonly cited policy was the Contracts for Difference (CfD) scheme, given its success in scaling deployment and reducing the cost of renewable technologies such as offshore wind. Many respondents noted parallels between GGRs and offshore wind, most notably the challenge of securing investment in capital-intensive technologies where longer-term cash flows are uncertain or volatile. A range of stakeholders from industry, academia and the third sector proposed that similar mechanisms could be suitable to support early-stage deployment of GGR technologies. Some respondents suggested that payments for negative emissions from BECCS could be integrated with CfDs to encourage deployment of BECCS in the power sector. Feed-in Tariffs were also identified as a successful mechanism for supporting deployment of renewable energy in various countries.

The UK Emissions Trading Scheme (UK ETS) was widely discussed as a potential long-term market for greenhouse gas removals. While the scheme does not currently recognise negative emissions, several respondents suggested that negative emissions certificates could potentially be integrated into the scheme in future. However, some stakeholders stressed that this would not be sufficient to support first-of-a-kind GGR projects due to price uncertainty and the low value of allowances.

Several respondents identified the Renewable Transport Fuels Obligation (RTFO) as a potential route to the utilisation of CO_2 captured through BECCS and DACCS. It was argued that a market for BECCS- or DACCS-derived biofuels could provide supplementary income to support the commercialisation of these technologies, while some respondents noted the potential for negative emissions to be considered for credits under this mechanism (similar to the way in which DAC is eligible for credits under the California Low Carbon Fuel Standard). One stakeholder stressed that any interaction between GGR policy and government support for low-carbon fuel must be fully understood to avoid the risk of double-counting.

A few respondents urged government to consider how direct payments in the agriculture, forestry and land use sector could be used to deliver nature-based and land-based GGRs, potentially through the government's environmental land management schemes.

Other policy mechanisms that were proposed to complement efforts to deploy GGRs included: the Industrial Carbon Contract; the Green Gas Levy (to supplement GGR revenues from CO_2 capture at biomethane plants); and Regulated Asset Base models similar to those under development for nuclear power. One developer suggested that lessons could be learned from the procurement programme for Covid-19 vaccines.

Several respondents believed that GGR projects should be able to 'stack' revenues from different sources and incentive mechanisms. As such, it was argued that future government policy on GGRs should complement existing incentives and markets in order to maximise the viability of these projects.

Q12: Are price instruments or quantity instruments likely to be more effective in encouraging and sustaining deployment of GGRs? Or will a combination be required?

Number of responses: 33

Overall, the majority of respondents believed that a combination of price instruments and quantity instruments will be required to encourage and sustain the deployment of GGRs. A handful of respondents indicated a straight preference for price-based mechanisms, while only a few believed that quantity-based policies are likely to be more effective.

Stakeholders identified a variety of advantages and disadvantages associated with price instruments. The most widely cited benefit was the greater level of revenue certainty offered by price instruments compared to quantity instruments, giving investors and project developers greater confidence to invest private capital. Price instruments were also considered to be suitable for supporting a wide range of GGRs, including new and potentially expensive first-of-a-kind technologies. However, a small number of stakeholders raised concerns that price-based policies are likely to favour lower-cost GGRs such as nature-based solutions, or could have a distorting impact on wider carbon markets.

The main advantage of quantity instruments was considered to be their ability to guarantee that a minimum, baseline quantity of carbon removal is achieved. It was argued that this will help to ensure sufficient volumes of greenhouse gas removal are brought to market to meet the UK's emissions reduction targets. However, several stakeholders expressed concern that quantity instruments alone are unlikely to differentiate between technologies and may result in only the cheapest GGR options being deployed. To address this risk, some respondents suggested that separate obligations or minimum quantities could be required for each GGR technology to ensure that a variety of options are commercialised. Other common concerns included the potential for price volatility and reduced investor confidence in the early stages of technology deployment, and the challenge of guaranteeing actual quantities of carbon removal.

Given the merits and risks of each type of policy, most stakeholders agreed that a combination of price and quantity instruments is desirable to promote GGR deployment. A number of respondents expected that the balance of price and quantity instruments will change over time as the market develops. Many of these stakeholders said that price mechanisms will be vital to attract investment in early GGR projects, while quantity-based mechanisms could play a larger role in reaching targets for removals once technologies have matured. However, robust economy-wide carbon pricing was often cited as the most effective way to create sustained demand for negative emissions.

Some stakeholders suggested that the choice of price or quantity instrument will depend on the type of GGR technology and the scale of deployment. A couple of respondents believed that the detailed design of the policy is likely to be as important as the choice of intervention itself, and the most important consideration for investors will be confidence in the security and longevity of the incentive.

Q13: How far should a policy framework aspire to be technology-neutral between different GGR options?

Number of responses: 48

Stakeholders expressed different views on the meaning of ‘technology neutral’ and the extent to which a policy framework should prioritise specific GGRs. Overall, most believed that government should aspire to bring a portfolio of GGR options to market, and that doing so is likely to require heterogenous support in the short-term given differences in the characteristics and costs of different technologies. However, it was generally agreed that the principle of technology neutrality should be followed in the longer-term once the sector transitions to a market-based mechanism.

Two separate but related issues were addressed in response to this question: first, whether government should prioritise specific GGR techniques in its strategy to reach net zero; and second, whether the policy interventions considered by government should be technology-specific or strictly neutral between different technologies.

One academic institute highlighted the possible tension between these questions by drawing a distinction between ‘being technology neutral’ and ‘maximising policy flexibility and minimising lock-in’. It argued that a strictly ‘technology neutral’ approach to policy design might result in deployment of a narrow set of options, while ‘maximising policy flexibility and minimising lock-in’ will require active government policy to pursue a diversity of solutions.

Should government favour specific GGR options?

There was a prevailing view that government should aim to develop a policy framework that would allow for a range of GGR options to emerge. Given the early development stage of most GGR techniques, several respondents cautioned against ‘picking winners’ based on the most promising or readily deployable technologies today. It was argued that premature decisions on optimal technology pathways would run the twin risks of (i) over-reliance on technologies that could be sub-optimal or result in failure, and (ii) ruling out technologies that could have been successful in the future. As a result, government was widely encouraged to bring forward a range of solutions, incentivise development and innovation in new technologies, and use the full range of options available to tackle an issue on the scale of global climate change.

However, a smaller number of stakeholders believed that government should prioritise certain techniques over others. A handful of charities and members of the public argued that affordable and ready-to-deploy nature-based approaches should be the focus of greenhouse gas removal policy, largely due to concerns around the cost and environmental impacts of engineered options. On the other hand, some industry respondents said that government should concentrate resources on engineered technologies that have potential to reach megatonne scale, provide permanence of storage, and help to address wider decarbonisation challenges through the production of low-carbon electricity, heat and fuels. Several developers and industry associations recommended a focus on DACCS and BECCS in the near-term, in order to gain early operational experience and help these technologies to become more cost competitive in the future.

Should policy interventions be technology-neutral or technology-specific?

While many stakeholders believed that technology neutrality is a desirable feature of government policy, it was widely argued that more bespoke mechanisms could be required for early GGR projects. Across a broad spectrum of respondents including developers, trade associations, charities, and academic institutes, there was a common view that a ‘one-size-fits-all’ approach is likely to be unsuitable in the short-term given considerable differences between the characteristics, costs, and co-benefits of GGR technologies. The main arguments in support of this view were as follows:

- GGRs are highly diverse in their cost structures, features, and application to different sectors, and as such may require different solutions and levels of support.
- A technology neutral approach could lead to a focus on the cheapest or most readily deployable GGR options today, potentially leading to under-deployment of more expensive technologies regardless of their permanence, scalability or longer-term benefits.
- A wide range of technologies should be brought to market to ensure long-term value for money.
- The design of any given policy mechanism might inherently favour certain outcomes and technologies, even if a broad range of technologies are formally eligible to compete.
- A broad range of incentives across different types of GGR will be needed to avoid adverse impacts and risks associated with any one particular method, and additional policies may also be required to mitigate any negative impacts.

- Different technologies may bring co-benefits in addition to carbon removal, which should be properly recognised in the policy framework.
- Policy should consider how specific GGRs might interact with existing policies in different sectors.

A few stakeholders suggested that the policy framework should be guided by a set of overarching standards and principles, such as minimising externalities, rigorous sustainability criteria, and permanence of storage. It was said that this could result in a wide range of GGR technologies being incentivised, potentially through a suite of policy mechanisms, provided that the core standards and principles are met.

Many GGR developers and trade associations argued that technology neutrality should not be introduced at an early stage of GGR deployment, as targeted support will be required to reduce costs and improve the commercial readiness of engineered technologies. However, it was generally agreed that technology-neutrality should be a long-term goal once technologies mature and a market-led mechanism becomes feasible.

In contrast, a small number of respondents believed that policy should be strictly technology neutral, and there should be no differences in support. This was on the basis that a technology-neutral approach would avoid over-reliance on particular technologies, enable discovery of the best combination of options, and ensure that each tonne of CO_2 removed is treated equally. However, some nuances and exceptions were recognised. One proponent of technology neutrality was opposed to different 'subsidy rates' for different techniques, but believed that payments should be appropriately weighted to account for the level of permanence, with a discount rate applied to non-permanent removals. Another research institute argued that there may be a limited case for technology-specific measures for a small number of promising or low-regret technologies, but stipulated that such measures should be clearly focused on specific innovation or deployment objectives and should be clearly separated from the wider framework of incentive mechanisms for GGRs.

One academic consortium noted the government should enact reform of the Climate Change Act to account for removal activities across all sectors, in order for the full range of removal techniques to contribute to meeting UK targets.

Q14: Could wider support for GGRs have any unintended effects on the development and commercialisation of technologies in other sectors?

Number of responses: 37

Most responses to this question highlighted the risk that incentivising GGRs could deter the development and deployment of low-carbon and zero-carbon technologies in other sectors. As well as the general risk of 'mitigation deterrence', respondents offered specific examples of how support for GGRs could hinder investment in particular technologies: for example, by diverting investment and resources away from hydrogen technologies and conventional point-source CCUS in the industrial sector and power plants, or weakening incentives for innovation in renewable energy.

A few respondents noted the risk of diverting finite supplies of biomass away from other sectors for use in BECCS. It was also suggested that support for GGRs may result in distortion of the carbon market, potentially crowding out more effective abatement activities and increasing the financial burden on consumers and taxpayers.

Some stakeholders discussed the potential adverse effects of GGR deployment on agriculture and the environment, such as land requirements for reforestation and biomass, risks to biodiversity, and the danger of chemical by-products produced by GGR technologies. A couple warned of the potential impact of GGR deployment on sectors that utilise carbon dioxide; for instance, one respondent expressed concern that incentivising GGR could divert carbon dioxide from the food and drink industry to sequestration projects, potentially leading to an increase in food prices.

However, many respondents believed that the risks of mitigation deterrence and other adverse effects can be minimised with effective safeguards, such as separating targets for emissions reduction and carbon removal, setting clear strategies and high standards for emissions reductions in specific sectors, and targeting incentives towards carbon-neutral practices.

Furthermore, a number of stakeholders argued that GGR deployment can bring positive benefits for decarbonisation in other sectors if managed carefully. For instance, it was suggested that deploying GGRs would allow time to coordinate economy-wide decarbonisation and ensure that the UK's decarbonisation strategy is implemented in the most efficient way.

International policy on GGRs

Q15: Are there any international examples that have proved effective at incentivising GGR? Why were they effective, and are there any barriers to taking similar action in the UK? Are there examples of international approaches that have not worked well?

Number of responses: 29

Stakeholders highlighted a limited number of international policy initiatives for GGRs. By a wide margin, the most common example was the 45Q federal tax credit in the USA, which was cited by a number of developers, trade associations and research institutes.

The 45Q scheme was widely considered to have been successful in incentivising deployment of CCUS in North America, allowing industrial facilities to earn $50 per tonne of CO_2 stored permanently and $30 per tonne of CO_2 utilised. The scheme was reformed in 2018, with eligibility extended to DAC projects. The main reported strengths of the scheme included the inclusion of non-CO_2 greenhouse gases, well-tested monitoring rules stemming from established practices, and the provision of a stable revenue mechanism which is stackable with other incentives such as the Californian Low Carbon Fuel Standard.

However, specific weaknesses of the 45Q were also identified. A few stakeholders raised concerns that the current value of the credit is unlikely to be sufficient to stimulate investment in large-scale DAC projects without further policy support. One stakeholder noted that the 45Q provides the same level of support for DAC as for conventional CCUS, despite its higher cost. Furthermore, a few respondents noted that a tax credit is mainly likely to benefit existing companies with significant tax liabilities, and may be difficult to access for start-ups and businesses with small profit margins.

A couple of respondents suggested potential ways in which the scheme could be adapted to work better in the UK. One stakeholder believed that the mechanism should be altered from a tax credit to a direct payment, while another noted that the UK is less accustomed to using tax credits as a decarbonisation lever. A research institute highlighted that the disbursement of 45Q credits is expected to sunset after 12 years, and suggested that the incentive should be extended over a longer time period; however, it also argued that the mechanism should not be extended by default for the life of the project, and that safeguards should be put in place to protect the public from inefficient spending or locked in windfalls.

A number of developers, academics, research institutes and trade associations highlighted the California Low Carbon Fuel Standard (LCFS), which sets carbon intensity benchmarks for full lifecycle emissions of transportation fuels sold or supplied in California. Under the CCS Protocol of the LCFS, credits can be generated by DACCS projects that remove carbon from the atmosphere anywhere in the world, and BECCS projects that supply transport fuel into California.

A key strength of the scheme was considered to be the value of credits, currently around $200 per tonne, which some respondents said was high enough to drive investment in engineered GGR projects. Another strength was the fact that CCS and DAC projects do not have to be located within California to earn LCFS credits, allowing UK companies to take advantage of the scheme. A couple of stakeholders noted that LCFS credits can be combined with the 45Q tax credit.

Stakeholders also identified some weaknesses in the LCFS. One research institute highlighted that the 100-year monitoring requirement of the scheme is viewed as onerous by industry. An industry respondent noted that the floating price is subject to volatility which adds a further risk factor for investors. They suggested that if the UK were to adopt a similar mechanism, the incentive should be set at a fixed level for at least the medium-term or the period of the contract, in a way similar to the Contract for Difference mechanism.

Schemes highlighted by other respondents included:

- The AB32 Cap and Trade programme in California, which provides a market and incentive for purchasing carbon offsets.
- ‘Project Carbdown’ – enhanced weathering and biochar field trials set up by the Carbon Drawdown Initiative.
- Longship, the Norwegian project on carbon capture, transport and storage. This will encompass carbon capture from Norcem’s cement factory in Brevik and carbon capture from Fortum Oslo Varme’s waste-to-energy plant, creating potential to remove CO_2 from the atmosphere.

- The Low Embodied Carbon Concrete Leadership Act (LECCLA) in New York State incentivises public procurement of concrete with the lowest lifecycle carbon content.
- The Australian Government's requirement for developers of the Gorgon oil and gas fields to capture and sequester CO_2 produced as a condition of their licence.
- In the State of Colorado, state policy explicitly encourages biochar production from locally available beetle-killed and fire damaged wood. This has purportedly led to the cheapest biochar in the United States.
- The 'Reducing Emissions from Deforestation and Deregulation' mechanism (REDD+), which was highlighted by one charity as a viable source of funds for nature-based solutions.
- The American Carbon Registry (ACR), which provides a framework for carbon trading and habitat restoration.
- The Humus Programme of the Ökoregion Kaindorf in Austria which provides farmers with a financial incentive to sequester carbon in the soil through the build-up of humus.
- One trade association highlighted a number of international codes and protocols for voluntary soil carbon markets, including: the Climate Action Reserve Soil Enrichment Protocol, Verra Verified Carbon Standard (VCS) program, and the 'BCarbon' soil carbon storage standard.
- The USDA Biopreferred program, which was set up to promote the use of biobased products through mandatory federal purchases and a voluntary labelling initiative. The respondent noted that there has been low take-up of the scheme, potentially due to the complicated certification process, perceptions that the scheme is uneconomical for suppliers, and a lack of awareness of the program.

Policy options for incentivising GGRs

Q16: Should the government introduce a tax credit, and if so, how should this be designed? Should it be provided only for specific GGR technologies or a broad range of methods? Would multiple, specific rates be effective at incentivising as much investment as possible?

Number of responses: 40

Stakeholders were divided on the merits of introducing tax credits to incentivise GGRs. While several respondents highlighted the success of the 45Q scheme in accelerating CCUS deployment in the USA, others believed that tax credits will not provide the long-term revenue certainty or bespoke support required for early GGR projects. A number of industry stakeholders said that tax credits could form part of the revenue stack if used in conjunction with other policy mechanisms.

Merits and drawbacks of a GGR tax credit

A diverse range of respondents believed that tax credits could be effective in supporting the development and commercialisation of GGRs, including a number of academic institutes, energy companies, trade associations, and developers. It was suggested that tax credits for GGR research and development may incentivise innovation in new technologies, while tax credits for capital investment or the purchase of negative emissions could also support their deployment and scaling up. A few respondents believed that a tax credit should be linked to an economy-wide tax on emissions, serving as a ‘carrot’ alongside the carbon tax ‘stick’.

A number of stakeholders highlighted the success of the 45Q federal tax credit in bringing forward large-scale CCUS projects in the USA. Its proponents argued that the 45Q provides a stable value for captured carbon and is not subject to the same potential volatility as carbon markets or carbon trading mechanisms. It was also noted that the credit was recently expanded to cover Direct Air Capture. Some respondents said that this could provide a model for a similar incentive to spur GGR deployment in the UK.

There were differing views on the type of GGR that would benefit most from a tax credit incentive. Some felt that tax credits would be more appropriate for lower-cost land- and nature-based projects, such as biochar, enhanced weathering, afforestation, habitat restoration, and soil carbon sequestration. Others believed that tax credits for capital investment could support large-scale engineered GGRs such as DACCS and BECCS, which are capital-intensive and provide easily measurable CO_2 removals.

However, many respondents argued that tax credits will not be suitable or sufficient to support investment in engineered GGRs. The most common concerns were that:

- The effect of a tax credit is limited by the tax status and arrangements of investors and developers, and incumbent industries with significant tax bills are likely to be at an advantage over smaller entities and start-ups.
- Tax credits do not provide the bespoke support and flexibility that different early-stage projects require.
- Tax credits do not provide long-term revenue certainty and are open to revision at short-notice; as such, they are not considered to provide the same level of security or investor confidence as other approaches such as private-law contracts.
- Tax credits are unlikely to cover the high upfront capital costs of large-scale engineered projects, unless set at a very high rate.

While acknowledging its success in the USA, stakeholders perceived a number of limitations to the 45Q tax credit and questioned the extent to which it can serve a model for the UK. Various respondents from industry and academia noted cultural-political differences in the use of tax credits between the two countries, arguing that US tax credits provide investors with a different risk profile than an equivalent credit in the UK. Furthermore, it was recognised that the 45Q provides only a part of the revenue stack for Direct Air Capture developers, with projects driven by a combination of revenues from different programmes including California’s Low Carbon Fuels Standard. One consultancy noted that more advanced and complex technologies such as DACCS and BECCS will require a greater level of support than conventional CCUS.

Other stakeholders argued that a tax credit approach is sub-optimal for incentivising GGRs on the grounds that it would over-complicate payment, place the burden of funding on taxpayers, and be less effective than other approaches in stimulating competition and cost reductions. Some project developers said that tax credits alone are unlikely to be sufficient to support deployment of engineered GGRs, but could form part of the revenue stack in conjunction with other policy mechanisms which provide long-term security. Another developer suggested that tax credits could be more appropriate for scaling up once technologies are more mature and costs per tonne are known.

Design of a GGR tax credit

Different stakeholders proposed that tax credits could be available to companies that invest in GGRs R&D, infrastructure, or negative emissions on a £ per tonne of CO_2 basis. Most respondents who expressed a view believed that a tax credit should be inclusive of a broad range of technologies and should not single out particular methods. However, there was a widespread view that different rates could be appropriate for different technologies depending on factors such as technology cost, stage of maturity, and wider environmental benefits. A couple of respondents suggested that a tax credit should distinguish between temporary and permanent removals, with priority given to methods that provide longer-term or permanent storage of CO_2. One developer believed that a banded approach with varying rates of support is incompatible with a technology-agnostic framework and would amount to ‘picking winners’.

A handful of respondents said that any tax credit must provide long-term certainty for investors over a number of years, with necessary safeguards or commitments to mitigate the risk of future changes in policy. Other recommendations included: allowing tax credits to be tradeable; extending eligibility to businesses that have already invested in GGRs to ensure that first movers are not disadvantaged; and ensuring that a tax credit can be accessed by companies of different types and sizes, not just those with large tax liabilities.

Q17: Should participants from specific sectors with historical carbon emissions be eligible to apply for the credit or should the credit be economy-wide?

Number of responses: 27

A clear majority of respondents believed that any tax credit should be economy-wide and available to all sectors on an equal basis. Given the significant levels of greenhouse gas removal that will be needed to reach net zero, it was considered that all sectors should be incentivised to develop and deploy GGRs, whether or not they have been responsible for historic emissions.

Some respondents said that it would be ‘perverse’ to only allow sectors with historical carbon emissions to benefit from a tax credit, while excluding lower-carbon industries. A couple of stakeholders went further and said there was a moral argument for high emitters, such as fossil fuel industries, to be excluded from any financial incentives for GGR. A few respondents believed that while a tax credit should be economy-wide, additional policy interventions such as obligations should be imposed on sectors with large historic emissions.

One research institute believed government could provide a higher incentive for hard-to-abate sectors, while still offering some level of credit on an economy-wide basis. An energy company said that government should undertake a systems-based assessment of the economy to clarify which sectors should be eligible for potential support under a GGR incentive scheme.

Q18: If the government were to introduce a GGR obligation scheme, which businesses and emitting sectors could this cover? How could such a scheme be designed to minimise competitiveness impacts and regressive passed-through costs (e.g. to consumers and bill-payers)?

Number of responses: 36

Merits of an obligation scheme

There was a broad mix of views on the desirability of a GGR obligation scheme. Several respondents of different types expressed support for such a scheme, suggesting that obligated parties could be required to offset a proportion of their emissions by investing in GGRs or securing negative emissions certificates to meet their obligations. Many of those who supported an obligation scheme noted that it adheres to the 'polluter pays' principle. Some suggested that the percentage of emissions the obligated party must compensate for should increase over time, reaching 100% by 2050 to guarantee delivery of the UK's net zero target.

However, a large number of stakeholders, particularly from industry, expressed concern around the dangers of introducing an obligation scheme while the GGRs sector remains at a nascent stage. Several respondents highlighted the risk that the limited market size in the early stages of deployment could lead to price uncertainty, higher costs, and lower investor appetite. A couple warned that this uncertainty could result in carbon leakage if obligated parties move outside the UK. As a result, these respondents considered that an obligation scheme will not be a viable approach until there is a mix of established technologies which can be deployed, giving obligated parties optionality and reducing price uncertainty.

One energy company argued that an obligation scheme would be "undesirably complex and prescriptive" in the early stages of GGR deployment, raising challenging questions in relation to the scale of the obligation, obligated sectors, routes for compliance, eligible technologies, buy-out prices, and other considerations. Other risks included: the challenge of giving market participants confidence and certainty on obligation certificate prices; the need for robust carbon accounting procedures for all eligible GGR options; and the danger of a market dominated by a small number of nearer-to-market GGR options.

However, despite the broad consensus that an obligation scheme is not appropriate to support the initial rollout of GGRs, many respondents from industry believed that such a mechanism could be suitable in the longer-term to help scale-up and diversify GGR technologies. A stakeholder coalition also proposed that DACCS could be included in the Renewable Transport Fuels Obligation, noting that DACCS projects are eligible to directly generate credits through the Californian Low Carbon Fuel Standard based on net atmospheric CO_2 captured and permanently sequestered.

Scope of an obligation scheme

While there were differing views on the exact scope of an obligation scheme, there was a general consensus that it should cover the heaviest emitting sectors.

Several respondents believed that the obligation should be imposed on producers, extractors or wholesalers of fossil fuels. It was argued that this could have a number of advantages, such as: targeting emissions at source; concentrating the requirement on a smaller subset of actors rather than downstream obligations on individual emitters; and placing the obligation on large industrial actors with the greatest capability to fund and deliver large-scale GGR. However, one trade association argued that it would be difficult to manage an obligation on fuel wholesalers to compensate for a percentage of the CO_2 content of the fuel they sell in the UK, due to the complexity of fuel supply operations and difficulty in determining CO_2 content at the point of delivery.

Other respondents believed that an obligation scheme should cover a wider range of large emitting industries – such as heavy industry, agricultural wholesalers, electricity generators, energy companies, and the transport and waste sectors. It was considered that applying the obligation to a diverse set of companies would mitigate the impact on any specific actors or set of consumers (e.g. due to passed-through costs), and minimise the potential for companies to explore loopholes. One stakeholder coalition proposed that an obligation scheme should initially cover fossil fuel suppliers only, before gradually expanding to cover electricity suppliers and suppliers of agricultural products (e.g. supermarkets).

One industry respondent believed it would be sensible if the threshold for inclusion in the UK ETS were also the threshold for inclusion in a GGR obligation scheme, while a trade association suggested that an obligation scheme could be applied to emitting sectors that are not covered by the UK ETS. An energy company encouraged government to undertake a systems-based assessment of the economy to clarify which sectors would be appropriate for inclusion in such a scheme.

Minimising adverse impacts

Several stakeholders highlighted the risk that a GGR obligation scheme could lead to regressive passed-through costs for consumers and billpayers, such as higher fuel/electricity bills and food prices. The potential competitiveness impacts of a GGR obligation scheme were also considered.

A number of respondents argued that an obligation scheme must be carefully designed to avoid excessive increased costs for consumers. However, some believed that passed-through costs are necessary and appropriate. A few developers, academics and trade associations argued that since the benefits of GGR affect the whole of society, the costs should therefore be distributed across consumers and businesses; yet it was also noted that socialising costs may have the unwanted effect of relieving pressure on obligated industries.

A few stakeholders proposed ways of mitigating undesirable impacts of a GGR obligation. For instance, a stakeholder coalition proposed the introduction of targeted levies, tax breaks, or compensating subsidies to mitigate the burden on obligated entities, as well as the indirect impact on final consumers. An industry respondent also suggested implementing a border carbon tax adjustment to prevent carbon leakage.

A trade association noted that obligations have worked effectively in the power (Renewables Obligation) and transport sectors (Renewable Transport Fuels Obligation), suggesting that lessons can be learned from these schemes in relation to keeping prices low and avoiding negative impacts. Similarly, an energy company which favoured the development of tradeable credits or obligation certificates to reward verified GGR activities said that the Renewables Obligation scheme provided the longevity, security and visibility of benefits needed to create investor confidence in that sector.

Other design proposals

One academic consortium proposed that government should consider an obligation scheme that is agnostic to whether the permanently stored CO_2 came from conventional CCS (e.g. captured fossil fuel emissions in industry) or greenhouse gas removal. It argued that this would encourage industry to fund point-source capture first, before shifting to GGR methods as options for conventional CCS are exhausted.

In contrast, a stakeholder coalition believed that an obligation scheme that combines the storage of fossil CO_2 (CCS) and atmospheric/biogenic carbon removal would fail to deliver the necessary incentive for deployment of engineered GGRs due to their higher cost. It therefore proposed that separate schemes will be required to drive deployment of CCS and GGRs.

Some respondents noted that a GGR obligation scheme would require robust lifecycle emissions reporting. One energy company believed that an obligation scheme could form the basis of a negative emissions trading scheme in the longer-term.

Q19: What other regulatory approaches could government explore to incentivise GGR deployment?

Number of responses: 29

Respondents proposed a number of other regulatory levers that government could consider to encourage deployment of GGR technologies. These suggestions included:

- Regulation to encourage carbon capture and sequestration from biomass, e.g. by banning or taxing combustion of forest residues, waste incineration, and anaerobic digestion of food waste without capturing and storing CO_2.
- Amending planning and environmental permitting requirements for carbon sequestration projects, including accelerated review of applications and lowering thresholds for Environmental Impact Assessments.
- Regulatory levers to strengthen soil carbon stocks, including robust baseline standards.
- Regulatory approaches to promoting uptake of nature-based solutions in agriculture.

- Regulation to realise the carbonation potential of construction and demolition waste.
- Regulation to require liming of inland water bodies.
- Regulation to encourage the utilisation of captured CO_2 into long-lived products such as concrete or plastics.
- Regulation to encourage the utilisation of captured CO_2 to manufacture low-carbon biofuels or sustainable aviation fuels.
- Regulated Asset Base (RAB) models to encourage investment in large-scale GGR projects such as DACCS.
- Regulation of voluntary carbon markets.

However, several respondents from industry were not in favour of regulatory approaches. It was argued that regulatory instruments will not be sufficient to address financial barriers (e.g. large upfront costs) and bring forward investment in large-scale FOAK projects. Instead, there was a strong preference for investable business models and support mechanisms which provide remuneration for negative emissions.

Many stakeholders who answered this question reiterated their preference for other policy levers explored through this Call for Evidence – such as contract mechanisms, feed-in tariffs, government procurement, obligations, and carbon pricing.

Q20: What are the merits and risks of introducing payment schemes for GGRs, potentially involving up-front grants or payments for each tonne of CO_2 stored? Which GGRs would be suitable for a payment scheme?

Number of responses: 45

Merits of a payment scheme

Across a range of stakeholders, there was broad agreement that grants and payment schemes could be an important tool to support early GGR deployment. The main advantage of payment schemes was considered to be their flexibility and potential to ensure that a range of technologies are brought forward. In particular, the following advantages were highlighted:

- Payment schemes can provide bespoke support for FOAK and early projects. This can include funding for pilots and demonstration projects, upfront grants to assist with high initial capital investments, and direct remuneration for negative emissions per tonne of CO_2 removed.
- Payment schemes can be tailored to the type and scale of GGR, so could attract investment in many different types of projects and technologies.
- Payments schemes can increase investor confidence by providing revenue certainty over the whole lifetime of the project and reducing uncertainty around market exposure. This certainty of income may be particularly crucial for start-ups and small businesses.

- Payments for nature-based schemes can be designed to incentivise ecosystem co-benefits alongside carbon removal, e.g. biodiversity, water quality, flood resilience, and health and wellbeing.

A handful of respondents believed there is a stronger case for introducing GGR payment schemes for nature-based solutions, due to their lower cost in comparison to most engineered solutions. Some proposed that payments for negative emissions could be integrated within payments for provision of 'public goods' under the government's environmental land management schemes, providing an incentive for farmers and land managers to adopt nature-based solutions.

A few charities and associations proposed that government should explore opportunities to develop a Soil Carbon Code to fund nature-based solutions and land management practices that sequester soil carbon, while achieving co-benefits such as improving soil health, biodiversity and water quality. Two respondents argued that payment schemes could be instrumental in supporting uptake of biochar, potentially alongside regulatory levers such as obligations or soil carbon standards.

However, a large number of developers, trade associations and research institutes believed that payments could also be a valuable tool for accelerating deployment of early-stage DACCS and BECCS projects. There were differing views on the value of grants and loans for large-scale engineered technologies. While some respondents believed that grants and loans will be necessary to enable the development and commercialisation of early DACCS and BECCS projects – for instance, by supporting capital costs – others argued that grants fail to address the high operational costs and market uncertainty facing technology developers. A general consensus emerged that payments per tonne of CO_2 removed would be more suitable for incentivising deployment, with a complementary role for capital grants.

A couple of industry respondents said that a payment scheme would likely need contractual backing to provide certainty for investors. One trade association argued that Contracts for Difference mechanisms are likely to prove more suitable for large-scaled engineered GGR projects, while simpler payment or contract schemes may be more appropriate for land- and nature-based GGRs.

Risks of a payment scheme

Of those who agreed that GGRs will be required to reach net zero, only a small number of respondents were opposed to payment schemes to support their deployment. Nevertheless, several stakeholders identified potential risks associated with this type of policy mechanism. The most common risks and concerns were:

- Increased burden on the public purse – with government taking on risks around financing, delivery and technical performance that could be borne by the private sector.

- Risk of sub-optimal use of taxpayer money on approaches that do not deliver the anticipated quantity of removals or are not the most cost-effective solutions.

- Risk of government paying a large share of the cost of removal at the wrong price.
- Failure to generate price discovery and potential for unintended industry windfalls.
- Placing a large responsibility on government to select projects and technologies to finance, and to decide on the level of early stage support.

A couple of stakeholders suggested that the risk of overpayment by government could be mitigated by open-book approaches, so that payment schemes stay at-cost plus a small margin. An industry stakeholder proposed that payment on delivery would be preferable to advanced payment schemes, given the risk that funded carbon removals may fail to materialise. Some developers and trade associations also noted the risk that payment schemes for FOAK projects could expose the wider CCUS network to GGR competition risk.

Other design proposals

Many respondents suggested that as technologies become more established and costs fall, payments could be reduced and a greater degree of competition can be introduced. Some favoured the use of competitive auctions to encourage broad participation and maximise value for money. There was a widespread preference to transition from direct payments to more market-based incentives over time.

A number of stakeholders noted that a payments scheme must be linked to clear standards for monitoring, reporting and verification. A few respondents, including developers and academics, suggested that payments should consider the permanence of storage, with short-term soil sequestration discounted relative to long-term geological storage.

A variety of respondents suggested that government could directly purchase negative emissions to offset a proportion of public sector emissions. Some also noted the need to consider how GGR payment schemes might interact with existing payment schemes in different sectors.

Q21: Could a contract scheme be effective in incentivising GGRs such as DACCS and BECCS? What would be the main challenges and limitations of such a mechanism, and how could it be designed to maximise its effectiveness?

Number of responses: 36

The case for a GGR contract mechanism

The vast majority of respondents to this question believed that contract mechanisms would be effective in incentivising engineered GGRs such as DACCS and BECCS. This view was supported by a broad range of stakeholders including developers, research institutes, academics, energy companies, consultants, and trade associations, who believed that government-backed contracts will prove attractive to investors by providing secure revenue streams and reducing the financial risk associated with upfront capital investment. Many stakeholders expressed a clear preference for contract schemes over other policy mechanisms.

Several respondents highlighted the success of the Contracts for Difference scheme in reducing cost and driving deployment of renewable technologies such as offshore wind. It was also noted that contract-based business models are currently under development for industrial CCUS and hydrogen production. As a result, a number of respondents believed that contract mechanisms could be suitable for supporting large-scale engineered GGRs as they are well understood by investors, and because these projects are likely to encounter similar risks such as high capital costs and uncertain longer-term revenues. Some industry stakeholders added that contracts can guarantee that a specific volume of GGR will be delivered over a given timescale, providing certainty for the government's net zero plans.

While most respondents believed that contract schemes would primarily be suited to large-scale GGRs such as DACCS and BECCS, a couple of respondents said that service contracts could also help to attract private investment in biochar given the high cost of pyrolysis facilities.

Only a small number of stakeholders opposed the use of contract mechanisms to support GGR deployment. The main concerns were that contract schemes: are better suited to large-scale projects and could restrict deployment of other technologies; carry significant risk if the GGR method is unproven and costs are high or uncertain; and place the cost of carbon removal on government rather than polluting industries.

A couple of stakeholders who supported the use of contracts nevertheless believed it is difficult to introduce competition into contract schemes, which could potentially lead to a lack of diversity and higher costs. An innovation centre said that while contracts can give confidence to investors in specific new technologies, this does not provide the longer-term policy certainty which is crucial for investment and innovation across a range of GGRs.

It was widely suggested that contract mechanisms are likely to be more important in the early phases of deployment. A number of industry respondents believed that a contract scheme should be designed to allow gradual phase-out of government support and a transition to a market-led mechanism as the sector matures.

Design of a GGR contract mechanism

A handful of respondents suggested that a contract scheme for BECCS and DACCS should be based on business models currently being developed for CCUS and hydrogen production to ensure consistency of approach. Two stakeholders from industry recommended that a power CfD combined with a separate payment for negative emissions would be suitable for power BECCS projects, ensuring that the value of both co-products are recognised (i.e. low-carbon electricity and carbon removal). In contrast, one energy company believed that a carbon CfD would be the most appropriate tool.

Alignment with other revenue sources was identified as a priority by a few respondents, who said that any contractual scheme for BECCS should complement revenue streams from decarbonised products (e.g. electricity, hydrogen, bioethanol) and other business models (e.g. contracts for electricity generation and hydrogen production). One trade association warned that business models will not provide an investable proposition if they are overly complex or misaligned.

Setting the appropriate price, time period, and method of awarding contracts were identified as the main challenges of designing a contract scheme for GGRs. A few stakeholders proposed that competitive auctions or tenders could be used to encourage value for money and reduced costs over time. Reverse auctions were suggested as a possible mechanism to procure carbon removals at low cost, though this was generally considered to be more appropriate at later stages of deployment once technologies have been proven. One research institute proposed that government could use a competitively awarded public procurement contract such as Carbon Contracts for Difference, with the contract benchmarked against a reference price (e.g. the prevailing carbon price) and the top-up paid by government.

An industry stakeholder argued that while developers are likely to seek long-term contracts, government should prefer shorter contracts, potentially at a higher initial price, on the basis that more auction rounds will enable price discovery. They also believed that a contract that pays on delivery will reduce the risk to government, as no payment needs to be made if the contractor fails to deliver. A handful of stakeholders suggested that technologies could be separated into different pots, auctions or tenders based on maturity or cost, similar to the introduction of separate CfD auctions for different types of renewable technology.

Other design considerations proposed by individual stakeholders included:

- Funding contracts using revenues from higher carbon prices.
- Stipulating that at least 51% of jobs created through GGR projects must be in the UK.
- Technology-neutral contracts to avoid favouring particular GGRs.
- Considering environmental externalities in contracts to ensure that land-use, water-use and biodiversity impacts are acceptable and the most sustainable forms of biomass are utilised.

Q22: What could a cap and trade scheme for negative emissions look like, and which sectors would you propose to be included in such a market?
Number of responses: 41

Could GGRs be included in a cap-and-trade scheme?

Most responses to this question discussed the feasibility of including GGRs in the UK's cap-and-trade system, the UK Emissions Trading Scheme (UK ETS), which launched on 1 January 2021. It was widely acknowledged that the UK ETS – like most cap-and-trade schemes – currently does not recognise or issue credits for negative emissions. Stakeholders identified a multitude of arguments for and against extending the scheme to include greenhouse gas removals, as well as various challenges that would need to be overcome in order to integrate GGRs successfully.

Many respondents suggested that the UK ETS could provide an effective market mechanism for incentivising GGRs in the longer-term. Under such a model, it was said that GGR projects could be allocated an allowance or 'credit' per tonne of CO_2 removed, which could then be sold in the market to emitters who require negative emissions to compensate for their remaining emissions. Industries participating in the UK ETS would therefore face an economic choice between abating their remaining emissions at their own facilities, purchasing certified GGR credits, or paying the carbon price. As an alternative to tradeable GGR credits, a couple of respondents noted that negative emissions could be permitted in a cap-and-trade scheme by allowing emitters to deduct negative emissions from their portfolio of positive emissions before paying the carbon price.

Three main arguments were put forward in favour of integrating negative emissions in the UK ETS: (i) the UK ETS is a well-understood and economically efficient mechanism which can provide both market push and pull for negative emissions credits; (ii) the market structure should encourage an efficient allocation of private capital between emissions reduction and carbon removal; and (iii) the burden of paying for GGRs would be borne by emitting sectors rather than government.

However, a broad consensus emerged that while the UK ETS could be considered as an option for supporting GGR technologies in the longer-term, this would not be a suitable mechanism for incentivising early projects. This view was shared by a range of technology developers, trade associations, academics, research institutes, and environmental consultants. The most common concerns pertained to low carbon prices in the near-term, uncertain revenue streams, and the practical difficulties of integrating negative emissions into the scheme, as summarised below:

- Near-term carbon prices will not be high or certain enough to drive investment in first-of-a-kind engineered GGRs and provide revenue certainty for developers.
- Early inclusion of novel GGR options would introduce volatility and uncertainty to the UK ETS, and potentially undermine the stability or effectiveness of the market.
- Treating emissions reductions and carbon removals as equivalent may encourage unwanted substitution and discourage efforts to reduce emissions.
- Uncertain carbon accounting for land-based GGRs could weaken the credibility of allowances.
- The introduction of negative emissions credits, including lower-cost nature-based solutions, could lead to decreased pressure on the overall carbon price. One respondent referred to the New Zealand ETS, where excess supply of offsets contributed to a sharp decline in the allowance price; this example was considered to highlight the risks of allowing excessive or cheap GGR credits in carbon markets.

Challenges of incorporating GGRs in the UK ETS

Despite concerns that the UK ETS is not suitable as a short-term solution for GGRs, many stakeholders believed that the scheme could play a role in supporting deployment in the longer-term once the carbon price matures and technology costs fall. Nevertheless, stakeholders urged caution when considering integration of GGRs in the UK ETS and identified a range of challenges that will need to be addressed:

1. **Impact on market structures** – The UK ETS was established as a mechanism to encourage emissions reduction rather than carbon removal from the atmosphere. Consequently, several respondents emphasised that the introduction of GGRs would need to be carefully designed and implemented to ensure there are no unintended consequences on market structures and the underlying carbon price.

2. **Emissions reduction vs removal** – There was a perceived danger that including negative emissions in the UK ETS could undermine mitigation efforts. A few stakeholders proposed that quotas or buffers will be required to prevent cheap nature-based offsets being used as an alternative to emissions reduction – potentially through limiting the overall amount of negative emissions credits, or setting a proportional cap on the number of credits that can be purchased.

3. **Cost variations –** It was acknowledged that different types of GGR vary significantly in cost, and that nature-based and engineered negative emissions credits will likely trade at different prices. Some respondents expressed concern that cheaper nature-based credits could be prioritised over more expensive engineered GGRs which may have higher long-term removal potential.

4. **Permanence and risk of reversal** – Some respondents highlighted the risks of integrating temporary or reversible GGRs which do not permanently remove CO_2. A few suggested that UK ETS integration would only be suited to permanent removals, based on rigorous carbon accounting and a full lifecycle analysis.

5. **Additional policy support** – A number of respondents across industry and the third sector believed that more targeted support for GGRs (e.g. government-backed contracts) will be required ahead of, and potentially alongside, their inclusion in the UK ETS, until the carbon price is sufficient to drive the market. It was suggested that carbon prices are unlikely to reach these levels until after 2030.

Instead of incorporating negative emissions within the UK ETS, a small number of stakeholders believed it would be preferable to create a separate market for trading negative emissions. There were a range of views on how such a market should be designed, though it was generally considered desirable for emissions reduction and carbon removal schemes to be linked in some way.

An innovation centre proposed that a nature-based GGR marketplace should be developed initially, allowing farmers and landowners to generate negative carbon credits from sequestration projects. Linking the GGR marketplace and the UK ETS would allow hard-to-abate sectors to purchase those credits to meet their ETS cap, initially in limited quantities to prevent over-purchase of low cost credits. It suggested that the GGR marketplace would eventually expand to include engineered GGRs once those technologies have matured. In contrast, one NGO believed that separate markets are needed for nature-based GGRs and engineered GGRs due to their different levels of permanence, with a view to potentially linking those markets by an exchange rate over time (e.g. with each tonne of geological storage equivalent to 1.5 tonnes of sequestration in trees or soil).

In the event that a GGRs market is integrated or linked with the UK ETS, most respondents who expressed a view believed that all participating sectors should be eligible to purchase negative emissions credits. Some noted that eligibility should extend to other sectors if the scope of the UK ETS is expanded in future. A couple of respondents said that a negative emissions market should be used to address high-emitting sectors that are not covered by the UK ETS, though others argued that doing so would create unnecessary complexity.

Some respondents expressed a preference for an obligation-based scheme or tax credit rather than integrating negative emissions in carbon markets or cap-and-trade schemes. One NGO opposed emissions trading in principle, and therefore did not support the development of a trading scheme for negative emissions.

Q23: The costs of different GGR technologies vary significantly. How could a cap and trade system address these differences? How could a cap and trade system be used to incentivise initial investment in any future emerging GGR technologies over a long-term trajectory?

Number of responses: 23

The varying cost of carbon capture across different GGRs was identified as a key reason why a carbon trading scheme alone may not be suitable to support the deployment of emerging GGR technologies. In the short- to medium-term, most project developers and trade associations believed that carbon prices will not be sufficient to incentivise investment in higher-cost FOAK projects. As a result, there were concerns that reliance on a cap-and-trade scheme – such as the inclusion of negative emissions certificates in the UK ETS – is likely to favour low-cost options such as nature based solutions.

A number of industry respondents recommended that any cap-and-trade scheme should be combined with more bespoke policy instruments to help address cost differences between technologies, mitigate price volatility, and ensure that early-stage GGR technologies are commercialised. Suggested policy mechanisms included capital support, subsidy schemes, or government-backed contracts to provide additional remuneration or guarantee a fixed price per tonne of CO_2 removed. A trade association recommended that tradeable negative emissions certificates should be used to offset the cost to government for payment and contract schemes tailored to specific GGR technologies. Alternatively, one campaign group proposed that different GGRs could be worth a different volume of negative emissions credits to create a level playing field.

A few stakeholders acknowledged that, even in the long-term, there may continue to be wide disparities in the price of different GGR techniques. These respondents generally accepted that a competitive market framework will favour less expensive GGR solutions, though one respondent believed that additional remuneration will continue to be required to cover the price difference.

Q24: What role can government play in encouraging more companies to make voluntary commitments to invest in GGR technologies in the UK? To what extent can this support innovation in, and deployment of, these technologies?

Number of responses: 32

While most respondents believed that voluntary action alone is unlikely to be sufficient, there was widespread agreement that voluntary carbon markets could play a useful supplementary role in supporting the deployment of GGR technologies. Furthermore, there was a clear demand from stakeholders for government to take a leading role in the regulation of voluntary offsets to provide trust in the market.

The role of voluntary markets

Several stakeholders mentioned the recent drive by large corporations such as Microsoft, Stripe and Amazon to invest in GGRs as part of their voluntary carbon neutrality commitments. This private sector appetite was cited as evidence of the emerging demand side of a negative emissions market.

However, there was a broad consensus among developers, trade associations and research institutes that voluntary carbon markets alone are unlikely to be sufficient to deliver large-scale GGR deployment in the short-term. The main reasons given for this were:

- The limited scale of voluntary markets and the low price of credits.
- Voluntary schemes do not provide the revenue certainty needed to attract investor confidence in large-scale first-of-a-kind projects.
- Voluntary markets have tended to favour low-cost options such as nature-based solutions, as opposed to engineered GGR technologies.

While voluntary markets were deemed to be insufficient in themselves, a few respondents believed that voluntary investment could be used to supplement income received through government support mechanisms.

Many stakeholders from industry, academia and the third sector expected voluntary markets to play a more important role in the longer-term, as the market matures and technology costs fall. However, a handful of environmental NGOs and charities highlighted fundamental concerns around the use of GGR projects in voluntary markets. The main concerns were:

- The difficulty of proving ‘additionality’, i.e. demonstrating that the project would not have happened without the offsetting money. A few respondents cited analysis which suggested that only 2% of projects in the UN’s Clean Development Mechanism “have a high likelihood of ensuring that emissions reductions are additional and are not over-estimated”.
- Voluntary offsets markets do not require companies to take other action to cut carbon emissions first, meaning that GGR offsets may undermine efforts to reduce emissions.

One charity proposed GGR offsets should only be used to remove historic emissions and should not be permitted as a means to compensate for ongoing emissions.

- In an unregulated market, there is a risk that the wealthiest industries will buy up all the lower-cost GGR offsets, to the detriment of other sectors which will also need to rely on offsets to reach net zero.

One NGO highlighted the risk of ‘climate colonialism’, where cheaper offsets in developing countries are purchased by actors in wealthier nations.

Government’s role in voluntary markets

Stakeholders generally agreed that government regulation of the voluntary market will be essential to facilitate investment and provide confidence in the legitimacy of removals.

Many stakeholders highlighted the lack of formal regulation of the voluntary market, with some describing it as a “wild west” of varying standards. In particular, respondents noted that there is currently no oversight or overarching set of standards to ensure that purchased removals are additional, permanent, and verified. It was suggested that this weakens public and business confidence in the integrity of removals, acting as a major barrier to private investment.

A consensus therefore emerged that government has a vital role to play in regulating the voluntary market by establishing clear monitoring, reporting and verification standards. Many respondents argued that this would provide confidence that companies are investing in removals that are genuine, additional and permanent. Some said that these standards could form the basis of a formal government accreditation scheme for offsets.

Several respondents proposed that government should provide a framework to enable companies to source and invest in high-quality carbon removals – for instance, by establishing a dedicated trading platform or a go-to list of approved projects or technology providers which meet the required standards. This would stimulate voluntary private sector activity by providing easy access to the market and simplifying the due diligence that customers need to undertake on GGR projects. Some industry respondents noted that government should consider how voluntary markets would interact with the UK ETS or other potential support mechanisms introduced for GGRs in future.

Stakeholders proposed a variety of further actions that government could consider to stimulate voluntary investment in carbon removals, such as:

- Publicly encourage UK companies to make voluntary investments in GGRs as a key pillar of corporate net zero strategies.
- Boost public and corporate awareness around the necessity for GGRs, including action to build public acceptability.
- Introduce an investable GGR framework which the private sector can interact with, and outline a transparent deployment pathway to 2050.

- Implement the recommendations of the Taskforce on Scaling Voluntary Carbon Markets – including the establishment of key criteria and standards, and a governance body to oversee the sale and purchase of carbon offsets and removals.
- Incorporate the Oxford Offsetting Principles into the market framework for voluntary removals.
- Work with international bodies to ensure that international carbon markets are underpinned by a robust and coordinated set of standards.

A couple of respondents suggested that the National Infrastructure Bank could play a role in catalysing voluntary investment in GGR projects. One developer believed there should be incentives for companies to invest in scalable novel technologies that will be required over the longer-term, as opposed to nature-based options that are cheaper and ready to deploy today. One charity said that important decisions need to be made about how GGR capacity should be allocated and which sectors should reduce their emissions further, rather than purchasing GGR offsets.

Summary of Responses to Chapter 3: Supporting and enabling policies for GGRs

Chapter overview

The third and final chapter of the Call for Evidence explored the physical and accounting infrastructure that will be required to enable deployment of GGRs at scale. It invited views and evidence from stakeholders on:

- The coordination of GGR deployment with wider policy on Carbon Capture, Usage and Storage (CCUS).
- Barriers to developing a robust monitoring, reporting and verification (MRV) system for GGRs.
- Principles for accreditation of negative emissions and approaches to regulation.

Coordinating CCUS and GGRs policy

Q25: What are your views on the government's intention to coordinate deployment of GGR technologies such as DACCS and BECCS in line with our stated CCUS ambitions, and how could we best do this?

Number of responses: 45

The majority of respondents agreed that it will be desirable to coordinate deployment of GGR technologies such as BECCS and DACCS with the government's wider CCUS programme, particularly the development of CO_2 transport and storage infrastructure.

Since T&S networks will be essential to facilitate deployment of BECCS and DACCS, it was often acknowledged that potential GGR projects should be factored into decision-making on pipeline capacity and routing. Several respondents also highlighted the potential for GGRs to optimise the use of new CO_2 infrastructure, providing economies of scale and essential early volumes of CO_2 into networks. A number of stakeholders believed it is important to align GGR deployment with the development of CCUS clusters, in order to allow initial projects to come forward in the late 2020s and capitalise on proximity to T&S, offshore storage sites, and low-carbon energy sources.

To promote further coordination, several stakeholders – predominantly GGR developers – said that government should consider setting a minimum target for deployed BECCS and DACCS capacity, building on the CCUS target outlined in the Ten Point Plan. Many also recommended that the development of business models for BECCS and DACCS should be accelerated in line with wider CCUS business models, to ensure that work can progress along the same timeline and informed investment decisions can be made for the first CCUS clusters. Some respondents sought clarity on how GGR business models will fit with the CCUS models currently under development.

Whilst there was broad agreement that policies on GGR and CCUS ought to be coordinated, a handful of stakeholders believed that certain limitations to this ambition should also be acknowledged:

- Beyond BECCS and DACCS, there are many GGR options that do not require integration with CCUS and CO_2 transport and storage networks.
- Large-scale GGR projects should not be incentivised just to make sure that CCUS infrastructure is optimally utilised.
- Government's priority should be to reduce current emissions before removing CO_2 from the atmosphere, and so deployment of DACCS should be a secondary concern after deploying CCUS.
- Policies should be flexible to accommodate technologies that provide different end uses beyond carbon sequestration, such as the use of captured CO_2 in the production of synthetic fuels or agricultural fertilisers.

A small number of respondents believed that government should not seek to deploy BECCS and DACCS at all, due concerns around the costs and lifecycle emissions associated with these technologies.

Monitoring, Reporting and Verification (MRV)

Q26: What principles would you wish to see in any accreditation scheme for negative emissions? How should the government regulate this? Any evidence relating to best practice of existing negative emissions MRV is welcomed.

Number of responses: 41

Most respondents to this question agreed that robust monitoring, reporting and verification (MRV) of greenhouse gas removals will be essential to their effective deployment, though it was noted that there is currently a lack of consistent approach to GGR accounting.

Principles for accreditation of negative emissions

The most commonly cited principle was that any accreditation approach should include a robust lifecycle assessment of negative emissions, including all upstream and downstream emissions associated with the GGR process. This point was often raised in relation to the harvesting, processing and transportation of biomass, particularly by environmental NGOs, campaign groups and academics.

Many respondents believed permanence of GHG storage to be an important principle. In particular, several stakeholders from industry suggested this should include consideration of how GGRs at greater risk of reversal (such as afforestation and soil-based options) are managed against those that permanently sequester carbon in geological formations.

Further principles were suggested by a few respondents, including:

- Transparency – to ensure quality and build confidence in GGR projects.
- Additionality – removals must be additional to what was likely to happen anyway, particularly where removal credits are purchased as offsets or traded in carbon markets. This requires a firm understanding of baseline scenarios.
- Independent verification/audit of removals – to prevent double-counting, and ensure integrity and compliance with carbon budgets.
- Internationally consistent – some respondents proposed that a standardised accounting framework and set of MRV standards should be agreed at an international level.
- Consideration of broader environmental impacts and other public goods – such as biodiversity, soil quality and societal benefits.
- Comparability and consistency – verification should be easily repeatable so that carbon removals can be measured on a consistent basis across different technologies, scales, locations and over time.
- Benefits stacking – making provision to reward positive impacts beyond GHG removal.
- Proportionality – MRV requirements should not be overly burdensome on operators, while ensuring accuracy and transparency.
- MRV should be based on direct measurement, where possible. If a calculation methodology is used, any models used should be robust, reliable and up-to-date.

Approaches to regulation

Many respondents believed that independent regulatory oversight will be necessary to provide accreditation of negative emissions and ensure confidence in the integrity of greenhouse gas removals. It was proposed that a regulator could:

- Establish and enforce principles and frameworks for carbon accounting.
- Take account of factors such as risk, level of empirical confidence and additionality.
- Track the latest science in MRV and manage how it is reflected in both compliance and voluntary carbon markets.
- Set the framework for allocating and paying for carbon credits.

A few respondents suggested that existing bodies could perform this function – such as the United Kingdom Accreditation Service (UKAS) or the Environment Agency – while others advised that a new regulatory body should be set up.

Examples of best practice

Many respondents referenced existing MRV methodologies for both emissions and removals, suggesting that these could be built upon to develop a comprehensive MRV framework and accreditation scheme for greenhouse gas removals.

Whilst no single example was raised consistently, frameworks that were highlighted included:

- Intergovernmental Panel on Climate Change (IPCC) carbon accounting principles.
- The EU's Renewable Energy Directive (RED) framework, containing sustainability criteria for biofuels and bioliquids.
- The EU/UK ETS MRV, which provides robust, transparent, and consistent data for the Schemes by utilising approved verifiers and adhering to global standards with feedback to UK accreditation services such as UKAS.
- Rules for the inclusion of CCS in the Clean Development Mechanism.
- ISEAL, a global organisation for credible sustainability standards.
- The Woodland Carbon Code, which has been developed with multiple stakeholders and continuously improved.
- The Taskforce on Scaling Voluntary Carbon Markets' recommendations on core carbon principles.

One trade association noted that Sweden has recently developed a methodology to calculate removals due to carbonation of concrete and cement products.

In addition, two standards/measurement bodies outlined potential approaches and technologies that could help reduce the cost of undertaking comprehensive MRV. For nature-based approaches, there are two primary challenges: reliability of carbon estimates and frequency of data updates. Companies have developed advanced machine learning algorithms that produce regular and accurate updates of nature-based projects' status, as well as models that use raw Satellite Earth Observation (EO) data to frequently and accurately quantify the above ground biomass of a project area. It was suggested that such commercially viable technologies can markedly increase the level of accuracy for large scale projects.

Q27: What are the most significant barriers to developing a robust monitoring, reporting and verification system for GGRs?

Number of responses: 43

Stakeholders identified a wide range of barriers to developing a robust MRV framework for GGRs.

Technical and scientific barriers

A number of respondents believed that different MRV methods are likely to be required for different methods of greenhouse gas removal, given the diverse characteristics of engineered and nature-based options. This was considered to be a significant barrier to developing a comprehensive and holistic approach to MRV for GGRs. The differing levels of permanence of carbon storage was identified as an additional challenge.

Several stakeholders noted the complexity of undertaking lifecycle assessments of GGR processes, especially when international supply chains are involved. A few of these suggested that there is a lack of transparency around supply chains, particularly in relation to BECCS.

Several respondents, including research institutes, energy companies and public bodies, also raised the point that the scientific data and evidence base is still incomplete for certain GGR methods – biochar was mentioned on multiple occasions. It was noted that evidence of how various factors such as climate, land use and soil changes affect carbon stocks is incomplete at present and may take time to develop.

Financial barriers

The cost of developing robust MRV procedures was highlighted by a number of stakeholders. Some respondents argued that MRV requirements should be proportionate, or that dedicated financial support should be available for improving MRV. However, two measurement bodies provided evidence of innovative new approaches and technologies that could help reduce the financial burden.

International barriers

A small number of respondents noted that GGR supply chains are typically international and developing an international framework for GGR cuts across many existing regulation systems (e.g. in the land and power sectors). This presents a major challenge to link MRV frameworks with existing regulation, avoid double counting, and monitor biogenic product carbon emissions. One academic argued that a standardised accounting framework for GGR should be adopted at the international level, to align GGRs with the Paris Agreement and its market mechanisms.

Coordination barriers

A few respondents acknowledged that numerous experts and institutions are working on different approaches to MRV and carbon accounting for negative emissions, leading to an uncoordinated approach to developing standards. It was suggested that a coordinated approach and leadership is required to bring together work on developing common standards and best practice.

Time barriers

Undertaking MRV, particularly in relation to MRV for nature-based methods, can be time- and labour-intensive. A couple of respondents noted that setting up a comprehensive system could take several years, with reference to the time taken to establish the Woodland Carbon Code.

Barriers specific to nature-based approaches

In addition to general barriers to developing robust MRV, a number of challenges specific to nature-based approaches were raised, such as:

- High levels of uncertainty and lack of agreed methodology in measuring soil carbon.
- Evidence on how climate, land management, and edaphic factors influence changes in carbon stocks remains varied and incomplete.
- Particular risks of reversal of CO_2 storage, if not maintained.

Annex – Figure 1: Overview of GGR methods

Vivid Economics' 2019 report 'Greenhouse gas removal policy options' summarised the evidence base in relation to the main GGR methods which could be deployed at scale in the UK by 2050. This was reproduced as 'Figure 1' in the Call for Evidence document, which served as the reference point for Questions 3 and 4. Figure 1 is copied below for reference.

An updated assessment of GGR methods and their potential deployment in the UK has subsequently been conducted for BEIS by Element Energy and the UK Centre for Ecology and Hydrology. The findings of the study have been published alongside this document.

Figure 1: Overview of GGR methods

GGR option	Description	Maturity (TRL*)	Indicative scale 2050 ($MtCO_2$/yr)	Notable risks to the environment or GGR ($MtCO_2$) potential
Engineering-based GGRs				
BECCS	CO_2 is captured and stored from combustion (or gasification) of biomass	TRL ~ 6. Bioenergy from biomass-based power plants is a mature technology, as is CO_2 capture in other applications, but the combination is largely at the demonstration stage	50	- Use of unsustainable feedstock - Competition for land may limit feedstock availability
Biochar	Storing carbon through partially combusted organic matter (char) by burying it in topsoil	TRL ~ 5. Method has been piloted, but not yet widely applied in UK	5	- Negative impacts on soil quality from both heavy metals and organic contaminants - Reversibility and irreversibility risks - Competition for feedstock with BECCS and, to a lesser degree, wood in construction
DACCS	Absorption of CO_2 directly from the atmosphere using amines,	TRL ~ 4. Only small-scale DACCS currently piloted	25	- Wastes produced from DACC process (absorbents etc.)

GGR option	Description	Maturity (TRL*)	Indicative scale 2050 ($MtCO_2$/yr)	Notable risks to the environment or GGR ($MtCO_2$) potential
	suspended on a branched framework			
Enhanced weathering	Spreading silicate minerals across soils to increase soil alkalinity, which increases absorption of acidic CO_2	TRL ~3. Needs to be piloted in the field	15	- Immaturity of technique means GGR potential in various local UK environments not yet fully understood - Impact on soil and water quality - Environmental impacts due to large-scale mining of required minerals - Reversibility and irreversibility risks
Magnesium silicate/oxide in cement	Replacement of carbonate in cement allows for potential absorption of CO_2 over concrete lifecycle	TRL ~ 6. There are several start-ups attempting to implement this	1	- Net GGR over lifetime of concrete not fully understood - Full life cycle impacts (including emissions from inputs) may be significant - Regulatory standards for concrete strength etc. may prohibit implementation
Wood in construction	Increased use of domestically produced wood in buildings (in nearly all new build homes) to permanently store carbon	TRL ~ 9. Approximately 50,000 homes a year already constructed with wood frames in the UK	5	- Ability to source enough domestic timber of appropriate quality - Processing and transportation may reduce GGR potential - Requires adjustments to building requirements and safety and quality assurance to enable sufficient scale
Nature-based GGRs				
Afforestation/ forest management	Increasing forest area to increase CO_2 absorption from the atmosphere	TRL ~ 9. Already widely practised throughout the world	15	- Biodiversity risks - Competition for land may limit deployment

GGR option	Description	Maturity (TRL*)	Indicative scale 2050 ($MtCO_2$/yr)	Notable risks to the environment or GGR ($MtCO_2$) potential
Habitat restoration	Rewetting and restoration of peatlands, wetlands, and other coastal habitats to enhance natural carbon absorption	TRL ~ 5. Significant knowledge and readiness around habitat restoration, but not focussed on GGR	5	- Expected that the evidence will imply this will not be a GGR but rather an emission reduction measure - Short-term emissions of non-CO_2 GHGs as a result of restoration - Competition for land may limit restoration or lead to indirect land use change emissions elsewhere
Soil carbon sequestration	Implementing land management options thought to increase soil carbon sequestration	TRL ~ 8. Ready for implementation and many of the practices are already used in some places	10	- Reversibility risk: After approx. 20 years soil becomes saturated, requiring maintenance to avoid CO_2 being re-emitted - Limited evidence of efficacy in the UK context and risk of possible increased emissions of N_2O

Note: *TRL: Technological readiness level, method of estimating technology maturity. TRLs are based on a scale from 1 to 9, with 9 being the most mature technology.

This consultation is available from: https://www.gov.uk/government/consultations/greenhouse-gas-removals-call-for-evidence

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