

Greenhouse gas removals independent review: call for evidence

Joint response from the CO₂RE Hub and the five GGR-D Demonstrators

About the GGR-D Demonstrators Programme

- The CO₂RE Hub and five GGR-D Demonstrators are pleased to provide this response to the GGR Independent Review's call for evidence. Together these projects form the £31.5m UKRI Strategic Priorities Fund Greenhouse Gas Removal Demonstrators Programme (GGR-D), which is investigating the potential for sustainable scale-up of greenhouse gas removal methods in the UK. The programme commenced in May 2021.
- The [CO₂RE Hub](#) coordinates across the GGR-D programme and carries out research on GGR technologies across the board. Areas of research include GGR evaluation and lifecycle analysis, legal and regulatory issues, economic policies, business models, monitoring, reporting and verification (MRV), public attitudes, socio-ecological systems and systems modelling.
- The five demonstrator projects include the [Biochar Demonstrator](#), the [UK Enhanced Rock Weathering Demonstrator](#) (UK ERW GGR-D), [Perennial Biomass Crops for Greenhouse Gas Removal](#) (PBC4GGR), [NetZeroPlus](#) (woodland creation and management) and [GHG Removal by Accelerated Peat Formation](#) (GGR Peat). These projects are researching individual GGR technologies and their potential GGR co-deployment. Research areas include scalability, co-benefits and trade-offs, and enablers and barriers, drawing on large-scale field trials, modelling, life-cycle analysis and research into public and stakeholder attitudes.

Key messages

- The GGR-D Programme has developed the evidence base for a key set of land-based GGR methods – enhanced rock weathering, biochar, perennial biomass crops for BECCS, woodland creation and management, and peatland restoration. The CO₂RE Hub has produced evidence on the key barriers and enablers for the sustainable scale-up of GGRs across the board.
- A clearer picture is emerging of land-based GGR removal potential, co-benefits and impacts and their spatial variation. Evidence on optimising the location of different elements of complex supply chains is also emerging. An evaluation framework co-created by the CO₂RE Hub with others shows the multiple considerations that affect the likely scale of each pathway and harmonises definitions to allow cross-comparison of GGRs, including both land-based and engineered GGRs. Data synthesis work is on-going.
- Extended research and monitoring would enable confirmation of whether and how removals continue over time, and the durability of carbon stored. It would also enable further investigation of the multiple ways in which GGRs might be co-deployed to increase the scale of removals. There is a crucial opportunity to extend the work being done at the field sites operated by the Demonstrator

projects in the GGR-D Programme, alongside policy support for multiple GGR methods designed to reveal useful information and enable data sharing.

- The UK should seek an optimised combination of different land-based GGR technologies, as part of a broad portfolio of GGR methods, informed by the emerging evidence including scenario modelling by the CO₂RE Hub and others. This is vital given competition for land, decarbonised electricity and other resources and the risk of carbon ‘leakage’. Realising the potential scale of removals will require careful policy choices about what kind of land-use or biomass use is prioritised, as well as around broader systemic considerations that affect the overall scale of removals required, the availability of decarbonised electricity and land, and environmental requirements set out in the Environment Act 2021.
- The CO₂RE Hub has commissioned analysis of cost estimates of GGR technologies to update BEIS 2021 GGR Methods technology assessment report. The Hub has also co-published estimates of the average MRV cost across all GGR methods; others have produced an expert assessment of DACCS and BECCS costs and scalability. There remain evidence gaps on the economic value of co-benefits and impacts
- Key enablers and barriers for all GGRs include: 1. regulation; 2. demand reliability, policy certainty and incentives; 3. MRV; 4. legal liability; 5. integration with wider land use and other environmental goals and 6. data. Evidence draws on interviews and workshops with local communities, farmers, project developers, investors and other stakeholders carried out across the GGR-D Programme.
- A comprehensive regulatory review by the CO₂RE Hub has shown that the regulatory landscape of GGRs in the UK is neither comprehensive nor tailored to GGR activities. Combined with the diversity of GGR techniques and legal regimes (across the UK’s four nations) this creates a fragmented and incomplete regulatory landscape.
- CO₂RE Hub research has shown that policy combinations, targeted to specific GGR technologies, and addressing both the supply and demand side of GGR, are vital to promote scale up and strengthen private sector confidence. Technologies require tailored policy for specific technological readiness levels (TRLs), as part of a staged strategy of sequenced policies in order to reach the stage of diffusion, in which the technology produces GGR as a viable commercial product. There are valuable lessons to be learned from policy sequencing for the offshore wind sector. Policy options also differ in their likely ability to attract private investment, with CO₂RE business model research indicating that public-private collaborations could be attractive to investors for technologies where innovation and cost reduction is key.
- The CO₂RE Hub’s forthcoming publication on *The UK State of CDR* shows that the UK hosts at least 110 carbon removal ventures either based in or operating within the country. While these are mostly small scale, they cover a wide range of methods and CDR activity across the UK exhibits clear regional clustering. There has been a notable rise in new ventures offering CDR enabling services—such as MRV technologies, and carbon marketplaces—which are increasingly attracting investment.
- The UK could play a strategic role in enabling effective GGR scale up internationally, by helping to address the current lack of institutional structure to foster the exchange of GGR data and capability building across countries.

5. What is the potential scale of GGRs in the UK?

Potential scale of GGRs

- BEIS commissioned an expert study on potentials and costs, published in 2021¹. While there are uncertainty bounds in those estimates, we believe they still serve as a useful basis for decision making at this time. We note updates to some specifics (see our response to Question 7; the Biochar Demo will address biochar costs in a separate submission). There are a number of nuances which we unpack as follows.
- Forecasting scale is difficult and dependent on policy. In discussions within the GGR-D Programme, researchers have raised the point that there is a considerable difference between what is technologically possible and what is either optimal or likely, given policy support via incentives and/or other enablers. Competition for land, biomass and other resources such as low-carbon electricity means that the scale depends on broader policy decisions such as what kind of land-use or biomass use is prioritised by government, and the rate of decarbonisation of the electricity supply – particularly where energy use is significant within a GGR’s supply chain. Competition for resources also exists between GGRs.
- CO₂RE is modelling scenarios involving multiple GGR approaches. We should seek an optimised combination of different land-based GGR technologies, as part of a broad portfolio of GGR methods. The scenario modelling will extend UKTIMES modelling to include biochar and enhanced rock weathering, and provide further insights on their roles within UK pathways to net zero, as well as their impacts on the economy and biodiversity.
- In the Climate Change Committee’s Seventh Carbon Budget balanced pathway, carbon removals occur in the agriculture and land use, and engineered removals sectors, with associated land-use and biomass implications². Enhanced rock weathering and biochar are included as engineered removals in this pathway for the first time in the light of emerging evidence, including from the GGR-D Demonstrators. Ambitious targets for peat restoration are included, but do not yet incorporate GGR potential³.
- **The CO₂RE evaluation framework sets out key considerations that affect likely scale of each pathway.** This framework has been co-created with the GGR-D Demonstrators, project

¹ Greenhouse gas removal methods and their potential UK deployment (2021)

<https://assets.publishing.service.gov.uk/media/616ff80ce90e07197b571c95/ggr-methods-potential-deployment.pdf>

² CCC February 2025 The Seventh Carbon Budget: Advice for the UK Government. Table 7.4.2 shows key values in the Balanced Pathway for land use, setting out deployment rates for land-based removals including peatlands, woodlands, energy crops, and other land-use transition drivers such as managed hedgerows and agroforestry. Figure 7.12.1 shows sources of abatement for Engineered Removals, including BECCS (power, energy-from-waste, other), DACCS, and enhanced weathering and biochar.

³ The emissions reductions associated with peat in CB7 are based on emissions factors for ‘standard’ peat restoration. More active forms of management could support elevated carbon dioxide uptake and reduced methane/nitrous oxide emissions relative to standard approaches. This is being investigated in the GGR Peat demonstrator.

developers and other stakeholders^{4, 5}. GGRs comprise diverse methods with complex supply chains that cross sectors and regulatory contexts, national infrastructure and private interests⁶; the evaluation framework enables comparison of different GGR methods on an even footing. Lifecycle analysis considerations have been brought to bear to harmonise the approach⁷ to assessing the climatic merit of a GGR intervention⁸, as well as wider co-benefits and impacts. In addition, researchers from across the GGR-D programme have adopted a data framework and mapped data availability on carbon removals, and environmental co-benefits and impacts of carbon dioxide removal interventions⁹.

- Policy should continue to support multiple GGR methods and be designed to reveal useful information. While evidence gaps remain, policies (and support) can be designed to help reveal information about costs, potential scale, and wider co-benefits and trade-offs; as well as to incentivise cost reductions. For now, support should ideally continue for a range of GGR methods. Policies that enable data sharing that would help speed up rates of learning would be valuable (see also response to Qu. 7).

Role of land-based and nature-based removals

- **There are at least four forms of carbon removal potential that are land-based and nature-based^{10, 11}.** First, habitat protection and restoration can provide carbon removal through the accumulation of soil carbon and biomass. Increasing wooded areas will likely be a major component, through either active tree-planting or ‘passive’ regeneration, such as fencing off areas from deer and/or livestock for trees to colonise and grow by themselves¹².

⁴ Butnar, I., Cox, E., Lynch, J., Strubelj, L., Brophy, A., House, J., Westbury, P.S., Workman, M., Waller, L., Patrizio, P., Ragazzi, I., Macinante, J., Richardson-Barlow, C., Rodway-Dyer, S., Ghaleigh Singh, N., Bogojević, S., Bellamy, R., Haszeldine, S., Smith, S., Martirosian, N., Mouchos, M., 2025. Scaling up Credible Carbon Dioxide Removals: CO2RE Indicators and Evaluation Framework. In preparation.

⁵ CO2RE Hub, GGR Evaluation <https://co2re.org/ggr-evaluation>

⁶ Westbury, P., Arlinghaus, J., Bellamy, R., Butnar, I., Cox, E., Fankhauser, S., Gilbert, A., Hepburn, C., House, J., Lynch, J., Martirosian, N., Mouchos, E., Rodway-Dyer, S., Smith, S., Waller, L. and Workman, M. (July 2024), Delivering Greenhouse Gas Removal in the UK: Priorities for the government, CO2RE policy briefing

⁷ Butnar, I., Lynch, J., Vetter, S., Gamaralalage, D., Tang, Y., McKechnie, J., Foteneinis, S., Rodway-Dyer, S., Roder, M., Sogbesan, S., Hastings, A., Renforth, P., Brander, M. & House, J. 2024 A Review of Life Cycle Assessment Methods to Inform the Scale-Up of Carbon Dioxide Removal Interventions. Wiley Interdisciplinary Reviews: Energy and Environment, <https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wene.540>

⁸ For a removal to be genuine, it needs to deliver a net removal across the fully supply chain (encompassing sequestration and storage stages), while the timing of removal, permanence of storage and the risk of reversal are additional consideration.

⁹ Butnar, I., J. House, M. Thoppil, N. Martirosian, E. Mouchos, J. Lynch, S. Vetter, D. Gamaralalage, Y. Tang, J. McKechnie, S. Foteneinis, S. Rodway-Dyer, M. Röder, S. Sogbesan, A. Hastings, P. Renforth, M. Brander, R. Brown, C. Price, G. Hodgins, F. Deng, B. Emmett, J. Hatton, C. Pearce, R. James, S. Robinson, K. Gannon, J. Thornton, I. Bateman., 2025. Evidencing carbon removals and environmental co-benefits and impacts of Carbon Dioxide Removal interventions. Manuscript in preparation.

¹⁰ CO2RE Hub blog, Nature-based solutions and GGR: Q&A with Dr John Lynch <https://co2re.org/nbs-ggr-john-lynch/>

¹¹ Lynch, J. What types of CDR are ‘nature-based solutions?’ In preparation.

¹² NetZeroPlus is measuring carbon sequestration in forests, woodlands and hedgerows, and in naturally colonising land. For example, they have a demonstration site at the Knepp Estate in West Sussex.

- Second, habitats where trees would not naturally be present, and/or may not be the preferred land-use, can still provide carbon sequestration, with, for example, saltmarsh, mudflats, scrub, heathland and particularly re-wetted bogs¹³ all having potential to generate removals. In some cases, interventions on degraded ecosystems (such as drained peatlands) may transition them from net GHG sources to net GHG sinks. Climate mitigation is one of many reasons to deploy Nature-based Solutions in addition to carbon sequestration and benefits to ecosystem services and biodiversity¹⁴. However, the combined emissions abatement and GGR potential should be considered as part of the overall estimation of climate mitigation potential of Nature-based Solutions, and the accompanying cost-benefit calculation (rather than as a ‘co-benefit’ of GGR).
- Third, the land-sector could offer greater biomass supply for a variety of low-carbon uses such as biomaterials, sustainable fuels, biochar, and bioenergy with carbon capture and storage (BECCS)¹⁵. Depending on the type of biomass production and previous land-use, converting land for biomass production could either gain or lose habitat carbon in soils and standing plant biomass, with the broad expectation that biomass planting on carbon-depleted ex-arable mineral soils will more likely gain carbon, but biomass production on carbon-rich organic soils (including current pasture and organic peaty soils) may lose carbon, unless accompanied by mitigation measures such as raising water levels.
- BECCS comprises two components, 1) biomass feedstock production/ sourcing and 2) carbon capture and storage. The effect of carbon removed by BECCS at GGR is maximised if the biomass feedstock involves the use of fast-growing lignocellulosic feedstocks such as energy grasses (e.g. *Miscanthus*), or short rotation coppice (SRC) willow, or short rotation forestry which produce high yields with low inputs. In addition, as they are perennials, there are reduced annual emissions of greenhouse gases from cultivation. The net primary production of biomass crops means that BECCS will deliver GGR faster than tree planting, as well as the regular “banking” of the carbon fixed through photosynthesis, and so has an important role within the mix.
- Fourth, enhanced rock weathering^{16, 17} and biochar are ‘novel’ technologies which can potentially be applied at scale in the agricultural sector. The use of biochar extends beyond land to construction, with numerous applications and products involving aggregates and building materials¹⁸ and it can also be used as a substitute for coking coal in steelmaking¹⁹.

¹³ GGR-Peat is demonstrating methods and technologies to turn degraded UK peatlands into effective and secure long-term greenhouse gas removal (GGR) systems.

¹⁴ CO2RE Hub, Nature-based solutions and GGR: Q&A with Dr John Lynch, <https://co2re.org/nbs-ggr-john-lynch/>

¹⁵ PBC4GGR is investigating the role of perennial biomass crops in supporting BECCS in the UK.

¹⁶ Beerling, D.J., Kantzas, E., Lomas, M.R., Wade, P., Eufrazio, R.M., Renforth, P., Sarkar, B., Andrews, G., James, R.H., Pearce, C.R., Mercure, J.-F., Pollitt, H., Holden, P.B., Edwards, N.R., Khanna, M., Koh, L., Quegan, S., Pidgeon, N.F., Janssens, I.A., Hansen, J. & Banwart, S.A. (2020) The potential for large-scale CO₂ removal via rock enhanced weathering on croplands. *Nature*, **583**, 242-248.

¹⁷ Beerling, D.J., Kantzas, E.P., Lomas, M.R., Taylor, L.L., Zhang, S., Kanzaki, Y., Eufrazio, R.M., Renforth, P., Mercure, J.-F., Pollitt, H., Holden, P.B., Edwards, N.R., Koh, L., Epihov, D.Z., Wolf, A., Hansen, J.E., Banwart, S.A., Pidgeon, N.F., Reinhard, C.T., Planavsky, N.J. & Val Martin, M. (2025) Transforming U.S. agriculture for carbon removal with enhanced weathering. *Nature*, **638**, 426-434.

¹⁸ See also The Biochar Demonstrator’s response to the Call for Evidence.

¹⁹ Safarian, S. To what extent could biochar replace coal and coke in steel industries?, *Fuel*, Volume 339, 2023, 127401, ISSN 0016-2361, <https://doi.org/10.1016/j.fuel.2023.127401>.

Geography matters – spatial variations

- Emerging evidence from the GGR-D programme demonstrators shows that for land-based GGRs, their efficacy and other characteristics vary spatially according to a range of factors including soil characteristics, local climate, type of farmland (arable, pastureland or upland) or type of peatland, for example²⁰. The quantity of carbon removal also depends upon land management practices.
- For tree-planting, there is an important distinction between *afforestation* (novel tree-planting) and *reforestation* (planting or regeneration of trees in previously wooded locations). Afforestation in inappropriate sites may not end up providing significant removals, particularly if highly carbon-rich soils are disturbed in order to plant trees.
- The relative location of different elements of the supply chain is a further consideration in deploying GGR; for example, proximity of quarries to agricultural land for enhanced rock weathering; or proximity of perennial biomass crop production to BECCS plants and carbon dioxide transport and storage infrastructure. For example, the Biochar Demonstrator has mapped the geographic distribution of certain feedstocks to identify the optimal locations for biochar production²¹. The Enhanced Rock Weathering Demonstrator has delivered a comprehensive spatial inventory of UK silicate rock resources suitable as feedstock for ERW alongside a detailed upstream supply-chain assessment, indicating up to 3.7 million tonnes per year of suitable waste fines from existing mines^{22, 23}. The opportunities will present themselves differently across the devolved administrations and local authorities according to local context.

²⁰ GGR-D demonstrator programme field sites at different locations are showing that carbon removal from biochar, enhanced rock weathering, perennial biomass crops, afforestation and peatland restoration are all location-specific. For example for enhanced rock weathering: Kantzas, E.P., Val Martin, M., Lomas, M.R., Eufrazio, R.M., Renforth, P., Lewis, A.L., Taylor, L.L., Mercure, J.F., Pollitt, H., Vercoulen, P.V., Vakilifard, N., Holden, P.B., Edwards, N.R., Koh, L., Pidgeon, N.F., Banwart, S.A. & Beerling, D.J. (2022) Substantial carbon drawdown potential from enhanced rock weathering in the United Kingdom. *Nature Geoscience*, **15**, 382-389.

²¹ For example, for food waste digestate, potentially an abundant feedstock for biochar, a LCA-TEA study highlighted the value of co-locating food waste anaerobic digestate facilities with biochar production: Gamaralalage, D., Rodgers, S., Gill, A. *et al.* Biowaste to biochar: a techno-economic and life cycle assessment of biochar production from food-waste digestate and its agricultural field application. *Biochar* **7**, 50 (2025).

<https://doi.org/10.1007/s42773-025-00456-0>

²² Madankan, M., & Renforth, P. (2023). An inventory of UK mineral resources suitable for enhanced rock weathering. *International Journal of Greenhouse Gas Control*, **130**. <https://doi.org/10.1016/j.ijggc.2023.104010>

²³ Madankan, M., *et al.* (2025) A spatio-temporal supply-chain framework for Enhanced Rock Weathering deployment at scale: a UK case study. *Communications Earth & Environment*, in press.

Co-deployment of GGRs

- Evidence on what happens when two or more land-based GGR methods are co-located is also emerging: for example, tree planting and perennial biomass crops can be combined with biochar or enhanced rock weathering^{24, 25}, while perennial biomass crops can be used alongside biochar in peatland restoration sites. In the case of biomass cropping, biochar or crushed basalt (for enhanced rock weathering) is added during the point of crop establishment. In addition, there is potential to use biomass crops that are adapted to waterlogging for delivering GGR whilst lowland peatland is being restored. Biochar application to re-wetted peat appears to increase biochar stability, reduce CO₂ losses from peat decomposition, and suppress methane emissions^{26, 27}. However few controlled experiments have occurred, and so the extent to which this can increase overall GGR potential is currently not well known.

Systemic considerations

- **Focusing on reducing energy demand lowers the pressure on, and the scale of, removals needed to meet net zero targets.** Collaborative research between UCL and leading UK Universities has shown that strong demand-side action, focused on avoiding unnecessary energy use, shifting towards cleaner energy vectors, and improving energy uses that remain unavoidable, can reduce final energy consumption by 50% by 2050 compared to today. This transformative change to our way of considering the energy system cuts the root cause of emissions, significantly lowers volumes of required GGRs, and drops the pressure on their early delivery²⁸. It is noteworthy that this can be achieved without compromise on future quality of life.
- The findings suggest that moderate policies that only "steer" the system would require 76 MtCO₂e engineered GGR by 2050, alongside an additional 40 MtCO₂e mitigation (i.e. fossil CCS) with infrastructure and geological storage implications. A more transformative approach could achieve net zero without engineered removals, relying instead on nature-based removals (56 MtCO₂e, over 60% from forestry) and reducing the size of the power sector by 40%.
- Most of the alternative land-uses focussing on carbon removal (both habitat restoration and biomass supply) will require **changes to the agri-food system** (e.g. dietary shifts, increased productivity, reduction in food waste, changes in trade balance) if there is to be a large amount of land made available.

²⁴ For example, co-deployment is mentioned for enhanced rock weathering here: Beerling, D.J., Leake, J.R., Long, S.P., Scholes, J.D., Ton, J., Nelson, P.N., Bird, M., Kantzas, E., Taylor, L.L., Sarkar, B., Kelland, M., DeLucia, E., Kantola, I., Müller, C., Rau, G & Hansen J. (2018) Farming with crops and rocks to address global climate, food and soil security. *Nature Plants*, **4**, 138-147.

²⁵ See also: Amann, T. & Hartmann, J. Ideas and perspectives: synergies from co-deployment of negative emission technologies. *Biogeosciences* **16**, 2949-2960 (2019).

²⁶ Jeewani, P.H.et al (2025). Greenhouse gas removal in agricultural peatland via raised water levels and soil amendment. *Biochar*, **7**, 39. [https://doi.org/10.1007/s42773-024-00422-2`](https://doi.org/10.1007/s42773-024-00422-2)

²⁷ Jeewani, P.H.et al. (2025). Rewetting alongside biochar and sulphate addition mitigates greenhouse gas emissions and retains carbon in degraded upland peatlands. *Soil Biology and Biochemistry*, **207**, 109814. <https://doi.org/10.1016/j.soilbio.2025.109814>

²⁸ Barrett, J., Pye, S., Betts-Davies, S. et al. Energy demand reduction options for meeting national zero-emission targets in the United Kingdom. *Nat Energy* **7**, 726–735 (2022). <https://doi.org/10.1038/s41560-022-01057-y>

Technology-specific potential for scale:

- Under present tree planting policies we might see a cumulative removal of about 20 MtCO₂ from forestry within England by 2050. That might reasonably be doubled if we move to the UK scale and apply comparable policies. This does not mean that present policies are optimal. Our best estimate is that efficient use of tax-payers money would require a significant increase in tree planting^{29, 30, 31}.
- The 7th Carbon Budget includes targets to restore 79% of upland peat, and to re-wet or raise water levels in 66% of lowland peat. These measures will reduce current emissions by around 9 Mt CO₂e yr⁻¹ by 2050. Incorporating active peatland management for GGR into restoration policy and management could provide 2-3 Mt CO₂e yr⁻¹ of additional net abatement by 2050.³²
- Kantzas et al. (2022) found that enhanced rock weathering could deliver net carbon dioxide removal of 6–30 MtCO₂ yr⁻¹ for the United Kingdom by 2050, representing up to 45% of the atmospheric carbon removal required nationally to meet net-zero emissions.³³

²⁹ Cho, F.H.T, Aglonucci, P., Bateman, I.J. and Day, B.H. Resilient tree-planting strategies for carbon dioxide removal under compounding climate and economic uncertainties, 2025, PNSA, 122(10), <https://doi.org/10.1073/pnas.2320961122>

³⁰ Bateman et al, A review of planting principles to identify the right place for the right tree for 'net zero plus' woodlands: Applying a place-based natural capital framework for sustainable, efficient and equitable (SEE) decisions 2022, People and Nature, <https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1002/pan3.10331>

³¹ Mancini et al, Biodiversity offsets perform poorly for both people and nature, but better approaches are available 2024, One Earth, 7:12. <https://doi.org/10.1016/j.oneear.2024.10.002>

³² Simon, R., Mitchell, A., Evans, C., Whitaker, J., Thomson, A. and Keith, A., 2021. Greenhouse gas removal methods and their potential UK deployment. [Greenhouse gas removal methods: technology assessment report - GOV.UK](#)

³³ Kantzas, E. P. et al. (2022), Substantial carbon drawdown potential from enhanced rock weathering in the United Kingdom. Nat. Geosci. 15, 382–389

6. What are the co-benefits of GGRs?

- Alongside its direct benefit of carbon sequestration, storage and (in some cases) emissions, the co-benefits and impacts of GGR involving land and biomass include effects upon (in no particular order):
 - Farmer incomes;
 - Employment
 - Food production
 - Food imports and exports and the associated ‘leakage’ of carbon through trade
 - Timber production
 - Wildlife habitat and biodiversity
 - Overseas biodiversity ‘leakage’ associated with trade
 - Water quality
 - Water quantity
 - Flood risk
 - Access to the environment and associated recreation and health effects
 - Soil fertility
- Both globally and in the UK, more is known about the co-benefits and risks of conventional GGR methods such as tree planting and habitat restoration than novel methods such as BECCS, DACCS, enhanced rock weathering and biochar³⁴. Research summarising co-benefits and impacts for individual GGR methods³⁵ also indicates that the evidence is relatively rich for Europe compared to other parts of the world. Co-benefits and impacts are a focus for the GGR-D field trials and UK-specific evidence is emerging (see examples below).
- Similarly to potential scale, co-benefits and impacts are site specific and are impacted by previous land management³⁶. Variations in co-benefits and impacts will often be substantial between locations and so careful consideration of the spatial aspects of GGR needs to be made. Social acceptability and social impacts will also be context specific according to the local socioeconomic, cultural and historical contexts³⁷, ³⁸.

³⁴ Smith, S.M. (2024) *ibid*.

³⁵ Prütz, R., Fuss, S., Lück, S. *et al*. A taxonomy to map evidence on the co-benefits, challenges, and limits of carbon dioxide removal. *Commun Earth Environ* **5**, 197 (2024). <https://doi.org/10.1038/s43247-024-01365-z>

³⁶ IPCC, 2023: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]*. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647

³⁷ Hurlbert, M., J. Krishnaswamy, E. Davin, F.X. Johnson, C.F. Mena, J. Morton, S. Myeong, D. Viner, K. Warner, A. Wreford, S. Zakieldeen, Z. Zommers, 2019: Risk Management and Decision making in Relation to Sustainable Development. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. <https://doi.org/10.1017/9781009157988.009>

³⁸ For example, the Enhanced Rock Weathering demonstrator has found in research with local communities living near field sites.

- Many studies assessing GGR methods look only at carbon balance, excluding some or all other potential effects³⁹. There is a further challenge where positive or negative impacts may be scale-dependent and vary over time and according to when a given GGR technology is applied, and so extended pilot studies and modelling need to be supported over time to provide the necessary insights. The inclusion of co-benefits in the monitoring, reporting and verification of projects across the lifecycle of the GGR method, avoiding a generic tick-box exercise around “sustainable criteria”, would ensure that insights are gained (see also response to Q7). Frameworks can help with designing monitoring approaches: for example, ecological monitoring for nature-based solutions⁴⁰. Again, enabling data sharing would be valuable.

Avoiding carbon ‘leakage’ through multi-functional land

- GGRs that change the use of land (such as woodland creation, perennial biomass crops) may potentially displace other valuable activities, particularly food production, or impact biodiversity in a negative way. This could adversely affect other countries to which food production or biomass planting are shifted.
- It can therefore be important to identify multifunctional land-uses, which provide removals alongside other outputs, and hence reduce ‘leakage’ risks. Practices that increase soil carbon in farmed land or incorporate tree cover within agriculture (both silvoarable and silvopasture⁴¹), for example, can maintain food output and may be a preferred option for some land-managers rather than entirely changing land-use away from agriculture. GGRs such as Enhanced Rock Weathering or Biochar can be used as soil amendments added to arable crops or other types of agricultural land (see also Qu 6 on co-benefits) and therefore do not require land-use change or compete with other land uses.

Implications for decision-making

- The range of co-benefits and impacts described above obviously makes the analysis more complex but there is absolutely no avoiding such challenges – and indeed the GGR programme has shown that varying co-benefits (and equally important, the impacts) of GGR implementation can be brought into decision making and significantly improve the overall value of land use⁴².
- The very strong connections between the environmental and economic co-benefits and impacts of any major land use change means that ‘indirect’ effects have to be included in any land use policy decision. A failure to consider these effects will lead to, at best highly inefficient decisions

³⁹ Butnar, I., Lynch, J., Vetter, S., Gamaralalage, D., Tang, Y., McKechnie, J., Foteneinis, S., Rodway-Dyer, S., Roder, M., Sogbesan, S., Hastings, A., Renforth, P., Brander, M. & House, J. 2024 A Review of Life Cycle Assessment Methods to Inform the Scale-Up of Carbon Dioxide Removal Interventions. Wiley Interdisciplinary Reviews: Energy and Environment, <https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wene.540>

⁴⁰ For example, for monitoring biodiversity and soil health: Warner, E., Giuliani, L., Campbell, G., Smith, P. & Smith, A. (January 2024), Biodiversity and Soil Health Metrics Tool – User Guide. <https://nbshub.naturebasedsolutionsinitiative.org/monitoring-outcomes/>

⁴¹ Silvoarable is a type of agroforestry where trees are planted at wide spacings and are intercropped with arable crops. With silvopasture, trees are combined with forage grassland and livestock production. [A guide to agroforestry - GOV.UK](#), Forestry Commission 2024.

⁴² Bateman et al. (2024) How to make land use policy decisions: Integrating science and economics to deliver connected climate, biodiversity and food objectives, Proceedings of the National Academy of Sciences (PNAS), 121 (49) e2407961121, <https://doi.org/10.1073/pnas.2407961121>

(i.e. wasteful use of taxpayers' money), and at worst result in costs outweighing the benefits of change.

GGR-specific co-benefits and impacts

- In the case of **biochar**, co-benefits include increased water and nutrient retention, reduced greenhouse gases and ammonia emissions from livestock, promoting soil microbes, moderating acidity. and potential reduced fertiliser use. Specifically, there is evidence that reductions in emissions of other greenhouse gases, nitrous oxide and methane, are achievable for peat, arable land and pastureland when biochar is applied, as well as ammonia as a non-greenhouse-gas from manures. However, more evidence is needed, including on where biochar can result in reduced fertiliser use⁴³.
- **Habitat restoration for GGR** can provide important co-benefits. Restoration may be undertaken primarily to support biodiversity or other ecological and environmental purposes (which may also be stated Government policy: see response to Q7), with carbon removals just one of several ecosystem services provided – the balance of which will depend on the habitat type and restoration pathway. It should be noted that the optimal restoration pathway for GGR will not always be the same as that for biodiversity or other ecosystem services, requiring some trade-offs to be made. For example, peat restoration for GGR would seek to maximise CO₂ uptake by productive plant species and avoid areas of shallow standing water that generate methane emissions, whereas restoration for biodiversity might aim for a low-growing mix of plant species and open water for wading birds. Climate adaptation may be a particularly important benefit provided by ecosystem restoration, alongside carbon removals providing mitigation⁴⁴. Another widespread and broad co-benefit from removals linked with ecological restoration may be improved soil health: with a recent focused look at soil health through the framework of the Sustainable Development Goals (SDGs) highlighting the opportunity to use this approach as a benchmark to identify co-benefits of soil organic carbon.⁴⁵
- It is important to understand the opportunity for co-benefits and trade-offs with **increased planting of energy crops**, as well as how crops fit into the agricultural landscape and farming system⁴⁶. There are also social and environmental co-benefits and trade-offs in relation to the location and scale of **BECCS deployment**⁴⁷. BECCS is discussed further in Question 11 on energy security.

⁴³ See The Biochar Demonstrator's submission to the Call for Evidence.

⁴⁴ Smith, A. and Chausson, A. (2021) Nature-based Solutions in UK Climate Adaptation Policy. A report prepared by the Nature-based Solutions Initiative at the University of Oxford for WWF-UK and RSPB.
<https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2021/10/nature-based-solutions-adaption-report.pdf>

⁴⁵ Giuliani, L. M., Warner, E., Campbell, G. A., Lynch, J., Smith, A. C., & Smith, P. (2024). Advancing nature-based solutions through enhanced soil health monitoring in the United Kingdom. *Soil Use and Management*, 40, e13164. <https://doi.org/10.1111/sum.13164>

⁴⁶ Reviewed for miscanthus by Hodgson et al. 2024, Upscaling miscanthus production in the United Kingdom: The benefits, challenges, and trade-offs doi.org/10.1111/gcbb.13177

⁴⁷ Donnison et al., 2020; Bioenergy with Carbon Capture and Storage (BECCS): Finding the win-wins for energy, negative emissions and ecosystem services—size matters, *GCB Bioenergy*, doi.org/10.1111/gcbb.12695

- Evidence on co-benefits for **Enhanced Rock Weathering** indicates increased soil pH, counteracting undesirable acidity in intensively farmed soils, and in some soils, lower levels of unwanted heavy metals in soil waters as they are taken up in secondary minerals that are environmentally stable⁴⁸. No significant impacts on crop yield have been observed in UK trials to date; marked yield increases have been reported for large-scale trials in the US Corn Belt⁴⁹. The use of rock dust has been shown to positively affect plant biomass and yield, with results comparable to those of traditional fertilisers. However, the degree of this impact varies based on several factors, including the local climate, soil conditions, the composition of the rock dust, and the quantity applied. Generally the impacts become greater over extended periods of time.
- Timber and other woody residues are produced as a co-product from **forestry**. Timber products serve as a low-carbon alternative to carbon intensive materials such as conventional concrete and steel. Residues can be used for heat, power, biochar and other products. Some of these substitution effects are commonly considered in studies looking at the climate change mitigation potential of forestry⁵⁰. Forest Research have also considered including substitution effects in the UK Woodland Carbon Code⁵¹. Importantly, the determination of these substitution benefits requires more development, as notable studies have found that past analyses likely overestimated mitigation provided⁵² and that the assumptions used are not sufficiently supported by the literature⁵³. It should be noted that there are, however, multiple uses of wood, some of which (e.g. pulp and paper) do not sequester carbon durably and so have a lesser climate benefit⁵⁴.
- As mentioned in Question 5, **researchers from across the GGR-D programme have adopted a data framework and mapped data availability on carbon removals, and environmental co-benefits and impacts of carbon dioxide removal interventions**⁵⁵. This work has highlighted the need for continued data collection over the long-term.

⁴⁸ Beerling, D. J. *et al.* Enhanced weathering in the US Corn Belt delivers carbon removal with agronomic benefits. *Proc. Natl Acad. Sci. USA* **121**, e2319436121 (2024).

⁴⁹ Beerling *et al.* (2024) *Ibid.*

⁵⁰ Matthews *et al.* 2022, Quantifying the sustainable forestry carbon cycle, https://cdn.forestresearch.gov.uk/2022/07/QFORC_Summary_Report_rv1e_final.pdf and Forster *et al.* 2021, Commercial afforestation can deliver effective climate change mitigation under multiple decarbonisation pathways, <https://doi.org/10.1038/s41467-021-24084-x>

⁵¹ Valatin 2021, Carbon storage and substitution benefits of harvested wood products, <https://cdn.forestresearch.gov.uk/2021/07/frn041.pdf>.

⁵² Harmon 2019, Have product substitution carbon benefits been overestimated? A sensitivity analysis of key assumptions, <https://doi.org/10.1088/1748-9326/ab1e95>.

⁵³ Howard *et al.* 2021, Wood product carbon substitution benefits: a critical review of assumptions, <https://doi.org/10.1186/s13021-021-00171-w>.

⁵⁴ House of Commons Environmental Audit Committee (2023), Seeing the wood for the trees: the contribution of the forestry and timber sectors to biodiversity and net zero goals <https://committees.parliament.uk/publications/40938/documents/199465/default/>

⁵⁵ Butnar, I., J. House, M. Thoppil, N. Martirosian, E. Mouchos, J. Lynch, S. Vetter, D. Gamaralalage, Y. Tang, J. McKechnie, S. Foteinis, S. Rodway-Dyer, M. Röder, S. Sogbesan, A. Hastings, P. Renforth, M. Brander, R. Brown, C. Price, G. Hodgins, F. Deng, B. Emmett, J. Hatton, C. Pearce, R. James, S. Robinson, K. Gannon, J. Thornton, I. Bateman., 2025. Evidencing carbon removals and environmental co-benefits and impacts of Carbon Dioxide Removal interventions. Manuscript in preparation.

7. What are the barriers to and enablers of GGR deployment in the UK?

- Research across the GGR-Demonstrator programme, including interviews with local communities, farmers, project developers, investors and other stakeholders, has identified at least six key barriers and enablers. These relate to the following aspects: 1. regulation; 2. demand reliability, policy certainty and incentives; 3. MRV; 4. legal liability; 5. integration with wider land use and other environmental goals and 6. data.

1. Regulation

- **A comprehensive regulatory review by the CO₂RE Hub** has shown that the regulatory landscape of GGRs in the UK is neither comprehensive nor tailored to GGR activities. Combined with the diversity of GGR techniques and legal regimes (across the UK's four nations) this creates a fragmented and incomplete regulatory landscape. Regulatory barriers vary in scale, as some can affect all UK jurisdictions, or all techniques, whilst others may be jurisdiction-specific or technique-specific. Through CO₂RE's extensive stakeholder engagement with both industry and regulators, certain emerging regulatory challenges have been identified⁵⁶.
- From the perspective of cross-cutting issues which apply to all four jurisdictions and are GGR technique-agnostic, it has become clear when considering legislative change to better facilitate GGR techniques that there is a 'regulatory paradox' across the UK, whereby there is insufficient evidence (e.g. environmental impacts, technological success rate, market capability) from GGR activities to justify time-consuming regulatory updates whilst employing the requisite precautionary principle which is fundamental to all environmental law. On the other hand, it is an extreme challenge for many GGR projects to generate said evidence without a regulatory scheme in place. This circular challenge is one which will not be easily overcome, but must be acknowledged and addressed in order for GGRs to progress and scale.
- Throughout the UK, there is also a challenge of accessibility to law and the ability of projects to identify which regulators cover their GGR activities. Large projects may have the capacity to identify the appropriate support from the designated regulator or their own legal teams with ease. Conversely, start-ups or new entrants can struggle to find the appropriate or efficient support/signposting. Legal inaccessibility forms both an operational barrier and a financial barrier which smaller projects may not be able to overcome, causing delay and risking exit from the sector.
- Planning law forms a notable challenge for all four UK nations, particularly for engineered projects such as BECCS. The time taken for GGR project developers to receive the necessary permissions/permits, and the overall accessibility and understanding of planning law as it relates to GGRs, were flagged as challenges by multiple members of industry across the UK. It is acknowledged that both industry and regulators are approaching the development of new GGR technologies for the first time, utilising planning/permitting systems which are not necessarily tailored to GGR projects. Future knowledge-sharing and early engagement practices between industry and relevant regulators may help to address some of these preliminary issues.

⁵⁶ Van Looy, M. 2025, GGR Regulatory Review, in preparation.

- In terms of jurisdiction and technique-specific regulatory gaps, it has been noted by multiple regulators that there is no appropriate legislation or regulatory structure in place within the four nations to govern enhanced rock weathering (ERW) activities beyond existing peripheral law such as environmental or waste. There is also little or no dedicated capacity within regulators of the devolved jurisdictions – Scotland, Wales and Northern Ireland - to address ERW in the near future, although it is recognised by regulators from all four nations that this is an area which needs to be explored in greater detail as evidence from projects emerges. With ERW operations underway in various locations throughout the UK, it is a concern shared by regulators that project readiness and deployment does not overtake regulatory governance, from a risk perspective. This risk varies depending on the jurisdiction, with Natural Resources Wales having flagged that ERW is unlikely to be operating in Wales in the near future, so the risk is not as great as it is in Scotland, where ERW activity is underway.
- It has been well-documented that existing waste law throughout the UK has posed a hindrance to biochar activities. Biochar is governed by waste law, creating onerous obligations and restrictions upon operators, using feedstocks for their biochar which are categorised as waste materials. The limitations this brings to scaling biochar activities are explored thoroughly in Strubelj (2025) and a letter address to Secretaries of State for DESNZ and DEFRA authored by Prof Colin Snape and Dr Steve Smith^{57, 58}.

2. Demand reliability, policy certainty and incentives

- Private sector investment decisions are shaped by demand reliability - who will purchase GGR credits, at what price, and over what timeframe. The inherent lack of reliable demand for removals and lack of long-term policy certainty has been identified as a key challenge faced by developers and financiers within the BECCS and DACCS space⁵⁹. This is fundamentally a demand-side issue: there is no clear customer base, and potential buyers—such as governments or corporations—face limited regulatory pressure or incentives to purchase removals at scale. In fact, early activity in the BECCS and DACCS spaces has largely been driven largely by voluntary private purchases and this volume is comparatively small, totalling less than two million tons of carbon dioxide to date⁶⁰. The absence of stable demand signals heightens market risk and deters private investment.
- On the supply side, some GGR technologies are capital-intensive, with high upfront costs, high weighted average cost of capital (WACC), and long time horizons before returns are realized. These factors create a mismatch with the risk-return profiles preferred by venture capital and institutional investors. Startups in particular struggle to raise finance due to uncertain unit economics, limited track records, and the difficulty of de-risking early-stage propositions. The lack of clear, investable business models—compounded by minimal performance data and uncertainty about how value chains will evolve—further undermines investor confidence. Many

⁵⁷ Strubelj, L; Ghaleigh, N S (2025) Biochar Regulation in the UK: A Wasteful Approach to Greenhouse Gas Removal <https://co2re.org/wp-content/uploads/2025/06/biochar-waste-regulation-pb.pdf>

⁵⁸ Letter to SoS Steve Reed MP and SoS Ed Miliband MP, 2025, 'Recommendations for supporting and accelerating biochar deployment in the UK' https://co2re.org/wp-content/uploads/2025/03/Biochar-Policy-Letter_final.pdf

⁵⁹ Survey conducted in [Yang et al. 2024](#), Policy support for BECCS and DACCS in Europe: the view of market participants, Environmental Research Letters.

⁶⁰ [Smith et al. State of CDR, 2nd edition, 2024](#)

GGR solutions remain unproven at scale or are too asset-heavy to align with conventional VC strategies, increasing both technology and operational risk.

- These risks are amplified by spatial and logistical challenges inherent to many GGR pathways, which often require proximity to low-carbon energy sources, CO₂ transport infrastructure, and appropriate storage sites. The time-intensive nature of building such enabling infrastructure—combined with regulatory delays, complex permitting processes, and the lack of integration between GGR and broader decarbonisation strategies—further complicates project development.
- Policy combinations, targeted to the specific GGR technologies, and addressing both the supply and demand side of GGR, can play an important role in strengthening private sector confidence.⁶¹ More detail on this is provided in the answer to Q9.
- At a systemic level, clear and stable regulatory frameworks are vital. Fast and predictable planning and permitting processes, as well as MRV standards (discussed in more detail below), are necessary to reduce regulatory risk and ensure high-integrity removals. Government must take a coordinating role in building enabling infrastructure—such as CO₂ transport pipelines, storage sites, and low-carbon energy grids—that GGR projects rely on. Spatial planning is particularly important for siting energy-intensive technologies like DAC (direct air capture) near suitable energy and storage resources.
- Consistent government signalling—through policy roadmaps, consultations, and coalition-building—can shape market expectations and reduce strategic uncertainty. Industry coordination, cross-sector partnerships (e.g. with oil and gas for geological storage), and transparent governance frameworks can accelerate deployment while ensuring inclusivity and innovation.
- **Evidence from the GGR Demonstrator project NetZeroPlus** finds that profitability and the balance of incentives across different land uses presents a major barrier to tree planting⁶². Farming profits, supported by public subsidies, make agricultural production a more rewarding activity than GGR. While tree planting appears reasonably supported by a few hundred **million** pounds of public funding over a **five-year** period, this is completely outweighed by the **billions** of pounds of public support provided **annually** for farming. The result is clearly reflected in the low uptake of grants for tree planting. It is difficult to assess whether implementation costs are significantly deterring implementation when the opportunity costs of foregone activities (notably agricultural production including subsidies) so outweigh the returns to tree planting. Our best estimates are the implementation costs would not be a significant barrier if the opportunity cost imbalance was addressed. Until this imbalance of profitability is addressed tree planting will be a

⁶¹ [Feng et al, 2025, Policy evaluation and selection to accelerate carbon removal deployment](#)

⁶² Bateman, I.J. et al, A review of planting principles to identify the right place for the right tree for ‘net zero plus’ woodlands: Applying a place-based natural capital framework for sustainable, efficient and equitable (SEE) decisions, *People and Nature*, 2023; 5:271-301. **p.288-289 (3.3.1 Agricultural output and 3.3.2 Subsidies and other incentives)** sets out how subsidies and incentives affect land use change/reduce incentives to move from agriculture into timber production.

minor activity for land users, prompted mainly by personal interest and a willingness to accept a net loss – a situation which holds few attractions for a vast majority of farmers and land owners who rely upon their land for income.

- The **Perennial Biomass Crops demonstrator** has examined barriers and enablers to upscaling Miscanthus and Short Rotation Coppice (SRC) willow feedstock for bioenergy and greenhouse gas removal in the UK through interviews with farmers and other stakeholders⁶³. A lack of policy certainty and certainty about markets was found to be a key concern among farmers, among other barriers.

3. MRV

- MRV research is currently dominated by the voluntary carbon markets. Developers work independently with no transparency in the absence of national or international legislation and regulatory frameworks. There is a large number of MRV protocols and scale up projects on various GGR methods, with vague definitions of baselines, system boundaries, monitoring parameters, sequestration duration or permanence of storage timescales. A good summary of the MRV protocols available per GGR method is provided in [Mercer et al. \(2024\): Introducing a new tool for monitoring, reporting and verifying CO2 removals](#), and the State of CDR 2nd edition (2024).
- MRV can be a barrier or enabler. On the one hand it can be confusing, as the absence of internationally agreed standards and the multiple regulatory efforts being developed in parallel leads to a complicated and not always consistent landscape, making comparison and oversight of CDR difficult for investors and governments alike. MRV can also be costly⁶⁴, as monitoring needs to be long term and ideally needs to track broader impacts. DESNZ and the EU are both addressing the gap in standardisation.
- On the other hand, MRV is an enabler if done well, as it can build trust, transparency and credibility, strengthening investor and public confidence and providing data to better inform future projects and funding decisions. Crucially, it can also better support the integration of CDR into markets and targets, and ensure requirements for liability transfer are met⁶⁵.

4. Legal liability

- Legal liability is a cross-cutting risk that affects all parties along the entirety of the GGR value chain⁶⁶. Varieties of liabilities include responsibility for storage reversals, routine environmental

⁶³ Ingram et al., 2025 “For all kinds of reasons, it hasn't happened”: A novel integrative perspective for analysing the barriers to biomass crops for bioenergy in the United Kingdom”, Energy Research & Social Science; doi.org/10.1016/j.erss.2025.103936

⁶⁴ Mercer, L; Burke, J; Rodway-Dyer, S (2024) Towards improved cost estimates for monitoring, reporting and verification of carbon dioxide removal. [Towards-improved-cost-estimates-for-monitoring-reporting-and-verification-of-carbon-dioxide-removal-.pdf](#)

⁶⁵ Mercer et al. 2024; State of CDR report, 2nd edition; Workman et al, 2022, [Establishing a large-scale Greenhouse Gas Removal sector in the United Kingdom by 2030: First mover dilemmas](#)

⁶⁶ Navraj Singh Ghaleigh, Justin Macinante, Déjà vu All Over Again: Carbon Dioxide Removals (CDR) and Legal Liability, *Journal of Environmental Law*, Volume 35, Issue 3, November 2023, Pages 377–400, <https://doi.org/10.1093/jel/eqad022>

impacts (e.g. surface and groundwater pollution, noise and odour) and land use planning considerations. Determining who is liable when a GGR project goes wrong and what are they liable for and to whom, requires a full understanding of the regulatory regime pertinent to a given GGR technology, which often involves a mix of generic pre-existing regulation and new rules designed to address the particularities of GGRs. Liability can have significant impact for GGR - for example, in the case that geological storage fails in the DACCS or BECCS context, whether liability should sit with the project developer or off setter is a key determinant of risk/reward allocation. Properly designed, liability rules enable the effective management of GGR risk and provide the certainty for the GGR to be investable, and socially and environmentally robust.

5. Integration with wider land-use and environmental goals

- Changes in land-use and management, and particularly ecological restoration, can provide further environmental benefits in addition to carbon removals. Achieving many of these environmental benefits is part of pre-existing government commitments, particularly those set out in the Environment Act 2021, and - given that changes to land-use and management are essential to meet these - there is the opportunity to link these up with planning for increased carbon removals. This can be realised both through setting out an agri-food strategy that can enable changes in land-use to occur, and direct specific shifts on-the-ground.
- A barrier to realising this is the continued lack of a coordinated strategy. The forthcoming Land Use Framework presents an opportunity to start to rectify this, starting with the recognition of the need and potential for land use changes in relation to both GGR deployment and wider environmental outcomes.
- An integrated strategy is also essential to assess and manage the potential negative impacts that can be associated with GGR (e.g. pollution), assessing whether and to what degree GGR-focussed actions are appropriate. This is once again scale- and context-dependent. For example, converting land to be used for biomass production for BECCS may generate environmental co-benefits in some locations, but negative impacts in others, restricting the amount below what is technically viable. Given there is a finite land area, and anticipating that it will be challenging to achieve very substantial change, the opportunity costs of choosing one alternative land-use over another should also be considered: if land is converted for intensive biomass production, this means it is not prioritised for ecological restoration, and decision makers should consider the balance of carbon against other environmental outputs that may therefore be foregone.
- Where GGR interventions require a change in land-use away from conventional agricultural production, this can have a significant negative impact on land valuations, eligibility for agricultural payments and access to credit. This acts as a barrier to several potential large-scale GGR measures including tree planting, habitat restoration and the cultivation of some biomass crops. Changes to eligibility rules for agricultural payment schemes would partly address this barrier.

6. Data

- As noted in response to Question 6, there remains an evidence gap around the wider positive or negative impacts of many GGR methods⁶⁷. Improved data need to be tracked, including outside of the UK, if removals are contingent on important inputs (e.g. imported biomass for BECCS generating removals domestically).
- For ecological restoration, there are many habitats that are likely to provide carbon removal and storage, but with very large uncertainties over quite how much⁶⁸. Overcoming some of these data gaps would enable better land-use prioritisation for removals, enhance the outcomes of interventions and also help develop modelling and mapping to support the inclusion of more land-based removals in the UK National Inventory Report (NIR). At present, there is not a clear pathway for some land-based removals to be included in the NIR (even if they are already happening), resulting in an additional barrier to their usage.
- Similar evidence gaps exist for other land-based removals (e.g. biochar, enhanced rock weathering), where extended research and monitoring is required to confirm whether and how removals continue over time, and the durability of carbon stored⁶⁹. Here there is a crucial opportunity to extend the work being done at the field sites operated by the Demonstrator projects in the GGR-D Programme. A number of sites across the UK, covering different removal methods and different environmental conditions, have been created as part of the Programme. But their funding comes to a close this year with no confirmed further funding from UKRI to continue. Extending their duration will be vital for improving understanding, while closing them now would be a major loss to UK and international GGR capabilities.
- There is an opportunity to create value through sharing data effectively if the appropriate incentives and mechanisms are in place, potentially benefitting all those involved in this nascent sector. Data on the environmental benefits and impacts (as outlined above), as well as quantification of removals and commercial data, for example, is particularly valuable, but much of it is currently proprietary and commercially sensitive. An independent intermediary would be needed to facilitate data sharing underpinned by the appropriate frameworks and infrastructure. The researchers have adopted a data framework and mapped data availability; this work has highlighted the need for continued data collection over the long-term⁷⁰.

⁶⁷ Butnar, I., Lynch, J., Vetter, S., Gamaralalage, D., Tang, Y., McKechnie, J., Foteneinis, S., Rodway-Dyer, S., Roder, M., Sogbesan, S., Hastings, A., Renforth, P., Brander, M. & House, J. 2024 A Review of Life Cycle Assessment Methods to Inform the Scale-Up of Carbon Dioxide Removal Interventions. Wiley Interdisciplinary Reviews: Energy and Environment, <https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wene.540>

⁶⁸ Gregg et al, 2021 Carbon storage and sequestration by habitat: A review of the evidence (second edition). Natural England Research Report (NERR094). <https://publications.naturalengland.org.uk/publication/5419124441481216>

⁶⁹ Beerling et al. (2025) Challenges and opportunities in scaling enhanced weathering for carbon dioxide removal. Nature Reviews in Earth & Environment, in press.

⁷⁰ Butnar, I., J. House, M. Thoppil, N. Martirosian, E. Mouchos, J. Lynch, S. Vetter, D. Gamaralalage, Y. Tang, J. McKechnie, S. Foteneinis, S. Rodway-Dyer, M. Röder, S. Sogbesan, A. Hastings, P. Renforth, M. Brander, R. Brown, C. Price, G. Hodgins, F. Deng, B. Emmett, J. Hatton, C. Pearce, R. James, S. Robinson, K. Gannon, J. Thornton, I. Bateman., 2025. Evidencing carbon removals and environmental co-benefits and impacts of Carbon Dioxide Removal interventions. Manuscript in preparation.

8. What is the economic cost of deploying GGRs?

- The CO₂RE Hub has commissioned ERM to update cost estimates for GGR technologies. The focus of this work is engineered removals, i.e. DACCS, a range of BECCS approaches, ERW and biochar, updating Technology Readiness Levels (TRLs) and costs for individual technologies. The update will follow the same methodology as the 2021 BEIS' Technology Assessment Report⁷¹, focusing on parts of the complex GGR supply chains, i.e. not covering full GGR supply chains due to data availability.
- Estimates of the average MRV cost across all GGR methods relative to the total cost of removal have been published⁷². However, the sample size is small; collecting detailed and accurate information on these costs is a challenge as little information is publicly available and data may be unknown or commercially sensitive.
- DACCS and BECCS costs and scalability assessment have been published based on the opinions of 34 DACCS and BECCS experts⁷³.
- There are evidence gaps on the economic value of co-benefits and impacts.

⁷¹ DESNZ and BEIS (2021) Greenhouse gas removal methods: technology assessment report.

<https://www.gov.uk/government/publications/greenhouse-gas-removal-methods-technology-assessment-report>

⁷² Mercer, L., Burke, J. & Rodway-Dyer, S. (2024): Towards improved cost estimates for monitoring, reporting and verification of carbon dioxide removal. <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2024/10/Towards-improved-cost-estimates-for-monitoring-reporting-and-verification-of-carbon-dioxide-removal-.pdf>

⁷³ Abegg et al. (2024): Expert insights into future trajectories: assessing cost reductions and scalability of carbon dioxide removal technologies.

<https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2024.1331901/full>

9. What approaches are there for transitioning away from public investment and attracting private investment in GGRs?

The role of ETS and Carbon Contracts for Difference

- The predominance of public investment in GGRs reflects the fundamental market failure of removals: there is currently no robust, self-sustaining market for permanent carbon removal. To this end, the integration of removals into the UK ETS can accelerate credible demand by way of allowing emitters to purchase removals to comply with the ETS cap: when the cost of compliance via abating or the purchase of reduction certificates is high, firms will turn to the purchase of removal certificates, stimulating private demand for GGRs⁷⁴.
- However, credible demand is not necessarily sufficient. In order to garner meaningful private investment, an instrument like ETS integration ought to be coupled with an instrument that offers investors confidence by way of de-risking investment. This can be accomplished by way of implementing carbon contracts for difference (CCfDs).⁷⁵ CCfDs guarantee a price per-tonne of carbon removed (the strike price) over a long-term horizon (typically around 15 years). This revenue-certainty boosts investor confidence, and the longevity of the contract makes the capital-intensive process of engaging in GGR technologies more appealing. While the selection of a reference price for CCfDs is ongoing, if removals are integrated into the UK ETS, the UK ETS price offers a clear and credible benchmark, making it a viable option for a reference price. By way of stimulating a credible source of demand while also de-risking revenue flows, this hybrid instrument helps mitigate some of the investment risk associated with GGR projects and incentivises more private investment into the space through indirect market creation⁷⁶.
- The introduction of a hybrid CCfD/ETS integration is not necessarily a good fit for all GGR technologies. Technologies in different technological readiness levels (TRLs) require tailored policy in order to reach the stage of diffusion, in which the technology produces GGR as a viable commercial product. A staged strategy of sequenced policies along the TRL chain can help achieve the end goal of widespread diffusion. For instance, grants/tax breaks for the basic/applied research stage, before turning to CCfDs for the deployment stage, and finally including integration into the ETS in the mature diffusion stage⁷⁷.
- Transitioning away from public investment for GGRs necessitates developing GGR technologies to the stage of deployment, at which point private actors can begin to invest more confidently. This confidence arises through de-risking and market creation, which can be achieved by way of long-term instruments such as CCfDs as well as the augmentation of the UK ETS to include high-integrity removals.

⁷⁴ [Feng et al, 2025, Policy evaluation and selection to accelerate carbon removal deployment](#)

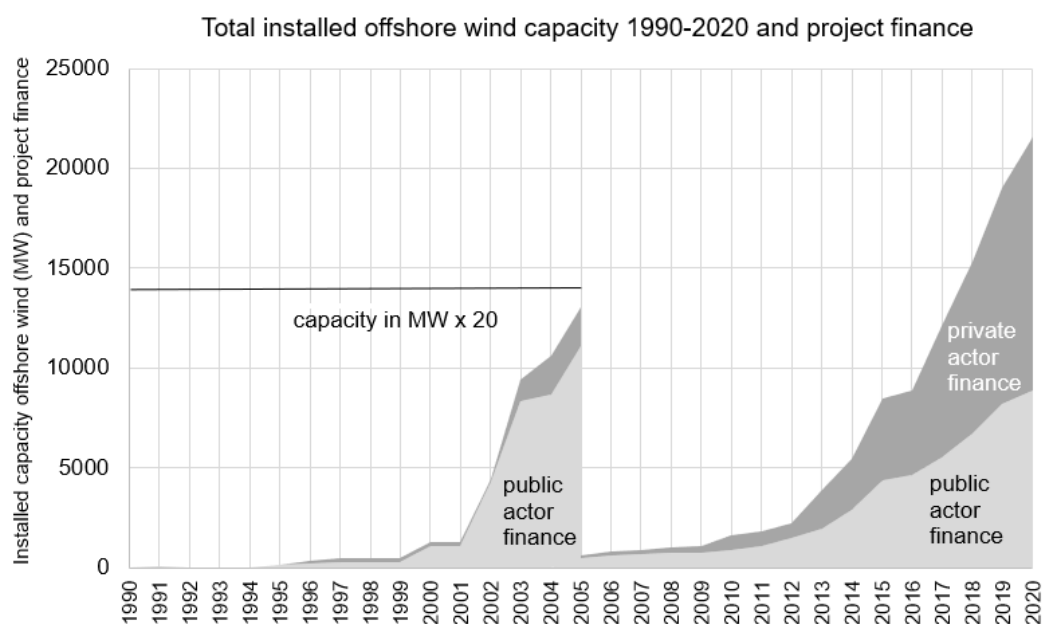
⁷⁵ Helm, Dieter and Hepburn, Cameron (2007) *Carbon contracts*. In: Helm, Dieter, (ed.) *The New Energy Paradigm*. Oxford University Press, Oxford, UK, pp. 63-75. ISBN 9780199229703; Richstein, J. C., & Neuhoff, K. (2022). Carbon contracts-for-difference: How to de-risk innovative investments for a low-carbon industry?. *IScience*, 25(8).

⁷⁶ See Feng et al (2025).

⁷⁷ Arlinghaus, J., Feng, S., Stemmler, J., Fankhauser, S. and Smith, S, 2025, [A taxonomy of policies to support geological carbon removal](#), working paper.

Learning from the Offshore wind Sector

- Research undertaken within CO₂RE has found relevant insights from the way that the UK **Offshore wind Sector (OSW)** evolved in the UK. The UK OSW sector is a useful analogue for the following reasons:
 - Costs have declined significantly from £200 MW/hr in 2008, and even after increases in the AR7 auction round, still represent dramatic reductions. The sequencing of policy instruments is useful as it has developed in 25 years to the scale commensurate with what the UK CDR sector needs to scale to by 2050.
 - In the 25 years this has realised ~14GW of operational offshore wind capacity, with an additional 4 GW under construction and contracts for a further 9 GW resulting in £45B in investment and over 30,000 jobs.
- The policy sequencing for OSW is a useful benchmark. The OSW sector development from the late 1990s required a series of interventions to be developed some concurrently transitioning from: the Renewables Obligation; Renewable Obligation Certificates (ROC); ROC banding; the Carbon Trust OSW Accelerator in 2008; Contracts for Difference in 2013. Disaggregation of the value chain to develop discrete Weighted Average Cost of Capital for each component of the value chain was introduced to allow innovation to focus on targeted components of the value chains. Overall, this resulted in the reduction in risk such that private sector actors were crowded in – as highlighted in the figure below.
- The figure below shows cumulative market share of private actor finance (dark grey) and public actor finance (light grey) taking risk for offshore wind installed capacity during 1990-2020. From 1990 through 2005 (left side) 0.6 GW was installed in total. For visibility in the graph, the capacity during this period is multiplied by 20. On the right side, cumulative market share from 2006 until 2020 is shown, during which time installed capacity reach 22 GW⁷⁸.



⁷⁸ Rentier et al., In Review

Effectiveness of policy instruments in attracting private capital

- CO₂RE has undertaken an exploratory modelling approach to analyse the potential effectiveness of different policy instruments to support the UK CDR sector⁷⁹. Using semi-structured interviews with private capital investors to generate a 15-year discounted cashflow (DCF), the modelling provides insight on the robustness of policies to attract private capital to CDR according to different Internal Rates of Return (IRR). The five business CDR methods assessed were: BECCS power, BECCS hydrogen, direct air carbon capture and storage (DACCS), enhanced rock weathering (ERW), and biochar. The six policy instruments considered were: ETS inclusion, carbon CfDs, a CO₂ storage tax credit, public-private collaborations (PPCs), build-operate-transfer (BOT), and private finance initiatives (PFIs).
- The results of the simulations found that high CfD strike prices (up to £175/tCO₂) and high ETS prices (£118/tCO₂ by 2030 and £172/tCO₂ by 2050) individually have little effect on the ability for CDR projects to attract private capital. When implemented in tandem, as being considered by the UK government, the ability for most business models to attract private capital improves. However, the financial performance of the business models still remains insufficient to attract the necessary private capital to scale the sector significantly.
- The analysis indicated that alternative policies are more effective in attracting investment to CDR. PPCs emerged as the most robust policy solutions due to more of the scenarios realising the IRR thresholds of different investors. PPCs are a popular and widely-supported approach to scale nascent sectors, including UK OSW in 2008 through the Offshore Wind Accelerator. Second most robust, behind PPCs, was a CO₂ storage tax credit, as adopted in the US Inflation Reduction Act.
- Many policy interventions are designed as broad, one-size-fits-all measures that apply uniformly across sectors and projects. These interventions are often limited in their ability to address the unique challenges of different projects because they must balance the interests and needs of a wide range of stakeholders, sectors, and industries. As a result, they may not fully align with the specific requirements of individual projects, leading to outcomes subject to fragility. In contrast, PPCs allow for a more customised approach: the terms, structure, and objectives of each partnership can be specifically designed to fit the project's context to ensure better alignment with both public goals and private sector capabilities. Table 1 shows the policy ecologies most suited to specific CDR business models given no policy support (Baseline 1) and integration on UK ETS + CfD mechanism (Baseline 4).

⁷⁹ Taricco et al (In Review) A robust decision-making approach for policy design to stimulate ‘firm-level’ private capital investment in possible net zero futures. Journal of Cleaner Production.

Market actor	IRR required	Baseline 1: No policy support					Baseline 4: Integration on UK ETS + CfD mechanism				
		BECCS power	BECCS hydrogen	DACCS	ERW	Biochar	BECCS power	BECCS hydrogen	DACCS	ERW	Biochar
Strategic investors	>8-10%	33.3%	0.0%	0.0%	11.1%	18.5%	54.7%	44.9%	0.0%	19.8%	40.7%
Infrastructure funds	>12-15%	3.7%	0.0%	0.0%	0.0%	14.8%	19.8%	32.1%	0.0%	3.7%	32.5%
Private equity	>20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.4%	0.0%	0.0%	6.2%

Table 1: The percentage of plausible futures tested in the scenario discovery analysis in which investments in five CDR business models are assessed against the minimum for different private sector investors, their specific Internal Rate of Return (IRR) requirements across presently proposed policy interventions. This was undertaken across 4 baseline scenarios ranging from no policy support, introduction of CDR allowances into the UK ETS only, introduction of CfD only; and integration of both CDR allowances to UK ETS and CfD. Baselines 1 and 4 only shown here.

Tree planting and habitat restoration

- **Tree planting and habitat restoration** are not expected to see large cost reductions through innovation (as evidenced by the BEIS GGR potentials report) and therefore a PPC/Accelerator model as suggested above for BECCS, DACCS, ERW and biochar is going to be less applicable.
- Evidence from **the NetZeroPlus Demonstrator** indicates that those who can afford to plant trees irrespective of opportunity costs have already done so (not just recently but over centuries). Significant change in the returns to tree-planting for GGR required for them to be taken up at scale. Two alternatives appear to be open: First, Government could increase returns to tree-planting for GGR either through increased subsidies or tax incentives. Second, regulations or market mechanisms could be introduced elsewhere in the economy to make carbon offsetting more attractive to firms. This might include taxation or an extension of trading schemes⁸⁰.

Biochar

- There are number of **applications of biochar in aggregates and building products** that are emerging. These do not require any public subsidy, although income is clearly accessible through the VCMs. However, the scale to which these applications may grow is uncertain and the challenge is to grow the market in mass agriculture and aggregates to *ca.* >2 Mtonnes CO₂ equiv. where biochar would then make a significant contribution to the UK's 2050 GGR target⁸¹.

⁸⁰ Cho, F.H.T et al. Resilient tree-planting strategies for carbon dioxide removal under compounding climate and economic uncertainties, PNAS, 2025, Vol. 122:10, <https://doi.org/10.1073/pnas.2320961122>

⁸¹ See The Biochar Demonstrator's submission to the call for evidence.

10. What are the roles and options for all GGRs, domestically and internationally, to balance the UK's residual emissions?

Domestic deployment of GGRs – current trends and implications for the future

- Based on evidence gathered for the forthcoming UK State of CDR report, the UK hosts at least 110 carbon removal ventures either based in or operating within the country, but most are early-stage, pilot, or pre-commercial, reflecting the sector's nascency, with many still refining their business models. These figures may underestimate actual activity, as some ventures—particularly those using conventional approaches like tree planting and peatland restoration or established methods like biochar—may not explicitly identify as CDR companies due to their broader environmental or commercial focus. Only four ventures have delivered carbon removal (all at kiloton scales) according to carbon credit registries⁸².
- Despite their small scale, the UK companies cover a wide range of methods: 11 out of the 15 CDR pathways recognised in the State of Carbon Dioxide Removal report are present. Biochar, BECCS, and DACCS dominate in terms of the number of companies. Land-based GGRs (e.g., afforestation, reforestation, peatland restoration, agroforestry) account for ~10% of the ventures. There has been a noticeable rise in novel CDR removal methods post 2020, indicating a shift towards solutions based on engineering technology.
- CDR activity in the UK exhibits clear regional clustering. London leads as the hub for company headquarters, benefiting from a concentration of investors, institutions, and policy networks. However, actual project deployment is more dispersed, shaped by factors such as infrastructure (e.g. CCUS clusters in the North), proximity to geological storage sites, the presence of research-intensive universities, and resource availability—particularly in the Midlands and Wales, where biochar projects are concentrated.
- International dynamics are already influencing deployment decisions. Three UK-founded DACCS ventures have located their pilots overseas, primarily in the US and Canada, likely due to more favourable permitting, infrastructure, or policy conditions. Conversely, only five international CDR companies have expanded into the UK—three of them in BECCS.
- There has been a notable rise in new ventures offering CDR enabling services—such as MRV technologies, and carbon marketplaces—which are increasingly attracting investment. Among companies founded post-2020, enabling ecosystem actors account for 46% of total funding, followed by DACCS (35%) and mineralisation-based approaches (7.6%). This reflects a maturing understanding of the CDR ecosystem and the essential role of enabling infrastructure and support services in scaling removals. These newer companies have raised an average of \$14.8 million, with a median of \$6.2 million—below the typical size of seed or early-stage public grants. This highlights the modest capital currently flowing into the sector and reinforces the need for public and blended finance to de-risk early-stage innovation and support scaling.

⁸² CDR.fyi <https://www.cdr.fyi/>

- Given this trend, there is a strategic opportunity for the UK to position itself as a global leader in CDR enabling services. With its strong financial services sector, expertise in carbon markets, and capabilities in digital innovation and data infrastructure, the UK is well-placed to build the backbone of the global CDR ecosystem.
- Assessment of the current landscape points to the following policy Implications for the UK's approach to GGR with regards to domestic deployment:
 - Leverage regional strengths: Deploy geographically tailored GGR strategies that align with local resource availability and infrastructure—for example, supporting DACCS clusters in Northern England and biochar deployment in Wales and the Midlands.
 - Balance the GGR portfolio: Maintain a balanced pipeline of land-based and engineered solutions by directing targeted support through R&D funding, grants, and procurement schemes.
 - Support early innovation: Continue investing in early-stage R&D and demonstration-scale pilots to accelerate innovation and identify scalable solutions.
 - Enable novel approaches: Establish clear pathways for novel methods to be tested, regulated, and de-risked, ensuring promising but unconventional technologies aren't excluded prematurely.
 - Maintain regulatory flexibility: Avoid technology lock-in by designing adaptive regulatory frameworks that can accommodate emerging innovations and shifts in scientific understanding.
 - Strengthen MRV and standards: Prioritise the development of robust MRV systems, carbon accounting standards, and international norms to help integrate engineered GGRs.

Supporting international governance, data sharing and capacity building

- As GGRs must be deployed more rapidly and in many more countries if the goals of the Paris Agreement are to be met, there is the opportunity for the UK to play a strategic role in enabling their effective scale up internationally.⁸³ The UK will ultimately benefit from developments in other countries if they enable cost reductions through technological learning, and if the UK chooses to make use of international transfers under Article 6 of the Paris Agreement.
- There is currently no institutional structure to foster the exchange of GGR data and capability building across countries. Mission Innovation⁸⁴, of which the UK is a member, provides some co-ordination – but it is limited in its duration, number of participating countries, and focus on technology innovation. A gap exists for an ongoing multilateral organisation to:
 - monitor project developments, financing and deployments;
 - build capacity across jurisdictions, especially in the Global South;
 - share learning, support co-operation and build participation over time.

⁸³ Smith et al. (2024) State of Carbon Dioxide Removal 2nd Edition, <https://www.stateofcdr.org/>

⁸⁴ <https://mission-innovation.net/missions/carbon-dioxide-removal>

- There are parallels between the current state of GGR and the state of renewables in the 1990s. At that time, wind and solar projects were a niche for committed environmentalists and engineers. Their path to success today (now providing essentially all new capacity additions for global power) stems in part from the creation of multilateral institutions such as IRENA and REN21,⁸⁵ to enhance international data sharing and capacity building. The UK has an opportunity to do similar for GGR, building on its domestic capabilities and co-operation with Mission Innovation partners and others.

Biomass feedstock for BECCS: domestic versus international supply

- Bioenergy with Carbon Capture and Storage (BECCS) could play a key role in delivery of GGR during the middle of this century before increased tree planting and other new technologies potentially play a bigger role in GGR by the end of the century. Feedstock could be sourced from the UK or internationally. If the crops are grown in the UK, it will require land in the UK and for farmers to grow them. It will also mean that any accumulation in soil carbon from the cultivation of the biomass crops, especially if they replace an annual crop, will be an additional carbon benefit to UK farming. Imported feedstocks provide the UK with the option to supplement UK cultivation but such biomass is more subject to competition for demand from others and will require greater auditing of its sustainable origin.
- The opportunity to grow biomass crops in the UK has been estimated to be as high as 8.5 million ha, but this potential land area was found to decline to 3.5 M ha when agricultural land classes (ALC) grades 1–3a were excluded, and to 1.4 M ha, when only ALC grades 4–5 were included⁸⁶. These land areas all exceed the upper planting range, of 0.7 M ha to 1.2 M ha suggested in the Climate Change Committee’s report, *Land Use: Policies for a Net Zero*, published in 2020. Expanding the growing of energy crops by around 23,000 hectares per year from the mid-2020s was predicted in the CCC’s report to deliver 2 MtCO₂e emissions savings in the land sector and a further 11 MtCO₂e from harvested products when combined with CCS by 2050. These estimates factor in minimising impacts on food production, but any dietary change, toward more consumption of plant-based protein, could increase this area further.

Biochar production

- Biochar production in Asia, Africa and South America is economically more favourable than in the UK due to a combination of lower-cost and readily available feedstocks, and the potential benefits of biochar being greater in agriculture due to relatively poor-quality soils⁸⁷. This reflected by recent investments of big tech, companies, for example, Microsoft in Bolivia⁸⁸.

⁸⁵ <https://www.irena.org/>; <https://www.ren21.net/>

⁸⁶ Lovatt, A., Sunnenberg, G. & Dockerty, T. 2014. The availability of land for perennial energy crops in Great Britain; doi.org/10.1111/gcbb.12147

⁸⁷ See The Biochar Demonstrator’s response to the Call for Evidence.

⁸⁸ Microsoft’s Major Biochar Deal Aims to Offset 1.24M Tonnes CO₂ (May 2025)

<https://carboncredits.com/microsofts-major-biochar-deal-aims-to-offset-1-24m-tonnes-co2/>

11. How can GGRs contribute to security of supply, with respect to the UK's energy system?

Biomass use

- The challenge for sourcing biomass from the UK for use in BECCS is that signals need to be given for the necessary investment and planting to be made. Prioritisation in the use of biomass is likely to change over the coming decades and its use prioritised to where it can have the greatest impact as well as its complementarity to the development/ decarbonisation of other sectors. Later this century, if DACCS becomes more deployable at scale, and as long as there is sufficient abundant and cheap electricity, the biomass could be diverted to Sustainable Aviation Fuels (SAF) and/or the manufacture of green chemicals, construction materials and steel, so helping to de-fossilise these important industrial sectors in the UK.
- BECCS can be a means by which the UK generates both renewable electricity and delivers GGR. A BECCS plant will have a lower efficiency, ie. generation capacity, than the same plant without BECCS but it will still contribute to the UK's security of supply. Moreover it offers the UK the ability to dial down CCS and increase energy generation at times of national need. Biomass is also needed to make biochar, another GGR, and so again its prioritisation between biochar manufacture and energy generation could be varied according to UK energy security priorities. (PBS Demonstrator)
- A biomass industry based on perennial crops such as Miscanthus, SRC willow, or short rotation forestry (SRF) will be more resilient than many other crops in the UK, because of established root systems and greater resilience to drought and flooding (Miscanthus and willow both produce aerenchyma, a specialised tissue in the roots). These crops when planted in buffer strips can help mitigate flood risk by affecting soil structure, trapping debris and reducing water flow.
- The point above about the changing use of biomass is also emphasised by UCL research on the role of bioenergy in global pathways stabilising global temperature under 2C, which shows that the introduction of alternative GGR technologies influences the demand and application of bioenergy⁸⁹. In the short term (to 2030), biomass replaces coal in electricity generation and industrial heat production. When BECCS is available, biomass is diverted to electricity generation with CCS for increasing the delivery of removals. However, BECCS is shown to delay the phase-out of fossil fuels and displace renewable energy generation, risking the achievement of climate targets.
- In terms of global trade, biomass trade represents 15% to 25% of total biomass supply in 2030. By 2050, energy crop production expands, providing 35% to 40% of global tradable biomass. The United States and China emerge as major importers of solid biomass by 2050. To increase security of supply, a diversified investment in multiple GGR technologies is deemed the most cost-effective approach.

⁸⁹ Butnar I., Broad, O., Solano Rodriguez, B., & Dodds, P. E. (2020). The role of bioenergy for global deep decarbonisation: CO₂ removal or low-carbon energy? *GCB Bioenergy*, 2020;00: 1–15.
<https://doi.org/10.1111/gcbb.12666>