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A Policy Framework for Bioenergy with Carbon Capture and Storage (BECCS)

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Overview

- To reach the UK's target of net-zero emissions by 2050, greenhouse gas removal (GGR) methods will be required.
- It is essential that investment in GGRs is not seen as an alternative to emissions reduction. GGRs should not be used to offset emissions from sectors such as power, road transport and heating that can reduce their emissions to zero.
- The government's Net Zero Strategy includes plans for large scale deployment of technologies that burn biomass with carbon capture and storage (or BECCS). This includes removing 5 million tonnes of CO_2 per year through BECCS and direct air capture by 2030.
- To achieve this goal, specific incentives will be required for the deployment of BECCS due to the complexity and financial risks involved. These incentives are required to complement the funding that is already being made available for small-scale innovation projects.
- Putting plans for BECCS into action also requires a cautious approach due to the significant risks of relying on this technology to meet emissions targets. The large-scale deployment of BECCS might be difficult to achieve on the timescale required. There is also uncertainty about biomass supply chain emissions and capture rates which could limit the extent of removals from BECCS.
- It is therefore important that BECCS deployment is subject to rigorous monitoring of performance, including biomass supply chain emissions, to ensure that it delivers substantial net removals.

What is the problem?

The UK is one of the first countries to legislate for a net-zero emissions reduction target. Emissions of all greenhouse gases need to be reduced to net-zero by 2050. Furthermore, the UK has one of the most ambitious medium-term targets. The government recently accepted the Climate Change Committee's advice on the sixth carbon budget, which includes a legally binding target to reduce emissions by 78% from 1990 levels by 2035.

Many countries will need to include the removal of greenhouse gases from the atmosphere within their plans to meet their climate change targets. Whilst emissions from electricity production, land transport and building energy use can be eliminated through the use of zero-carbon technologies within those sectors, greenhouse gas removal (GGR) methods will probably be required to offset remaining emissions from sectors that are hard to decarbonise completely – particularly agriculture, aviation and some industrial sectors. A range of GGR methods are available or in development. These include land-based solutions such as afforestation and changes in agricultural practices, and engineered removals that capture CO_2 directly from the air – or 'direct air capture'. Another potentially large scale GGR method is to combine bioenergy with carbon capture and storage (BECCS) (Royal Society and Royal Academy of Engineering, 2018). Bioenergy refers to biomass – plants – when they are used to generate energy. Biomass contains carbon, absorbed from the air during the plant's growth. When biomass is burned in a power station fitted with carbon capture and storage – a process by which the carbon emissions from the burning of a fuel are captured and buried underground – the overall result of the whole process is that the CO_2 that is taken out of the air during the plant's growth is stored underground. Useful energy is also generated along the way.

The UK government has started to develop its policy for GGRs in more detail as part of its Net Zero Strategy (HM Government, 2021). Most of the emphasis so far has been on supporting innovation. 24 small demonstration projects have been announced, including several that focus on BECCS and direct air capture. Additionally, a GGR research programme is funding 5 pilot-scale demonstration projects and a 'hub' that is carrying out interdisciplinary research. In parallel, the government published a call for evidence on GGRs in late 2020 (BEIS, 2020). The recent Net Zero Strategy confirmed plans to develop incentives for the deployment of GGRs and to extend regulations for monitoring, reporting and verification. However, much more still remains to be done.

This briefing focuses in particular on BECCS. While this technology is increasingly discussed as having the potential to deliver negative emissions at a large scale, it is also controversial due to the significant risks associated with deployment. The briefing is based on a recent report that explores the potential role of BECCS in the UK in detail (Watson, Broad and Butnar, 2021). It complements the *Together for Climate Action* explainer on BECCS, and discusses how much BECCS capacity might be needed to deliver the net-zero target. It also sets out a comprehensive policy approach to demonstrate and scale up BECCS whilst managing the technical, economic and environmental risks of large-scale deployment.

How much BECCS capacity might the UK need?

In our report (Watson, Broad and Butnar, 2021) we investigate five scenarios through which the UK could reach net-zero greenhouse gas emissions. Each scenario has different assumptions relating to BECCS deployment in the UK. BECCS removes between 38 and 80 million tonnes of CO_2 ($MtCO_2$) in 2050. This represents 9-19 percent of total GHG emissions recorded in 2020[1].This is similar to the range in the Climate Change Committee's sixth carbon budget scenarios (43.5 to 96.5$MtCO_2$). Natural removals and other engineered removals also play a role in our scenarios. They remove up to 38$MtCO_2$ from afforestation and changes in agriculture, and up to 50$MtCO_2$ from direct air capture. All scenarios meet the UK's legislated carbon budgets and include significant deployment of BECCS (see Figure 1). However, BECCS features prominently in all scenarios, which is why we focus on BECCS in particular here.

The first scenario, ***Net Zero***, assumes a strong shift away from fossil fuel use. It has an energy supply mix centred on renewables, with significant nuclear power investment, and an important contribution from bioenergy. This suggests that BECCS could remove 57 $MtCO_2$/yr by 2050[2], and prioritises the use of biomass for hydrogen production with CCS (40 $MtCO_2$/yr removal) over a smaller use of BECCS in power generation (17 $MtCO_2$/yr). This hydrogen is used in industrial sectors where clean electricity and direct biomass combustion also play a role.

The second scenario, *Engineered Removals*, is a much more optimistic scenario in terms of CCS efficiency and sustainable biomass availability. It includes BECCS removing 80$MtCO_2$/yr. Here biomass availability is in line with assumptions adopted by the Climate Change Committee. In this scenario imports of biomass account for 1.1% of total global sustainable biomass produced in 2050 . This biomass is diverted to power generation with CCS. The resulting negative emissions allow a much slower pace of fossil fuel phase out. By 2050 fossil fuels account for 47% of primary energy, vs 10.6% in the Net Zero scenario. Gas with CCS replaces biomass and electrolysis as the source of hydrogen production for industry.

To compensate for the higher residual emissions in this scenario, direct air capture is also deployed at scale and removes 50$MtCO_2$/yr. The combined deployment of fossil CCS and BECCS also increase rapidly from capturing 18$MtCO_2$ in 2035 to over 140$MtCO_2$ by 2050. Achieving this will be very challenging. Previous analysis for the UK has suggested that potential scale up of CCS infrastructure in the first decade could, at best, reach between 2 and 8$MtCO_2$ per year.

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1 Provisional data for 2020 recorded GHG emissions of 414.1Mt CO_2e in the UK.
2 Global biomass availability is assumed to be 100 Exajoules (EJ) in 2050.

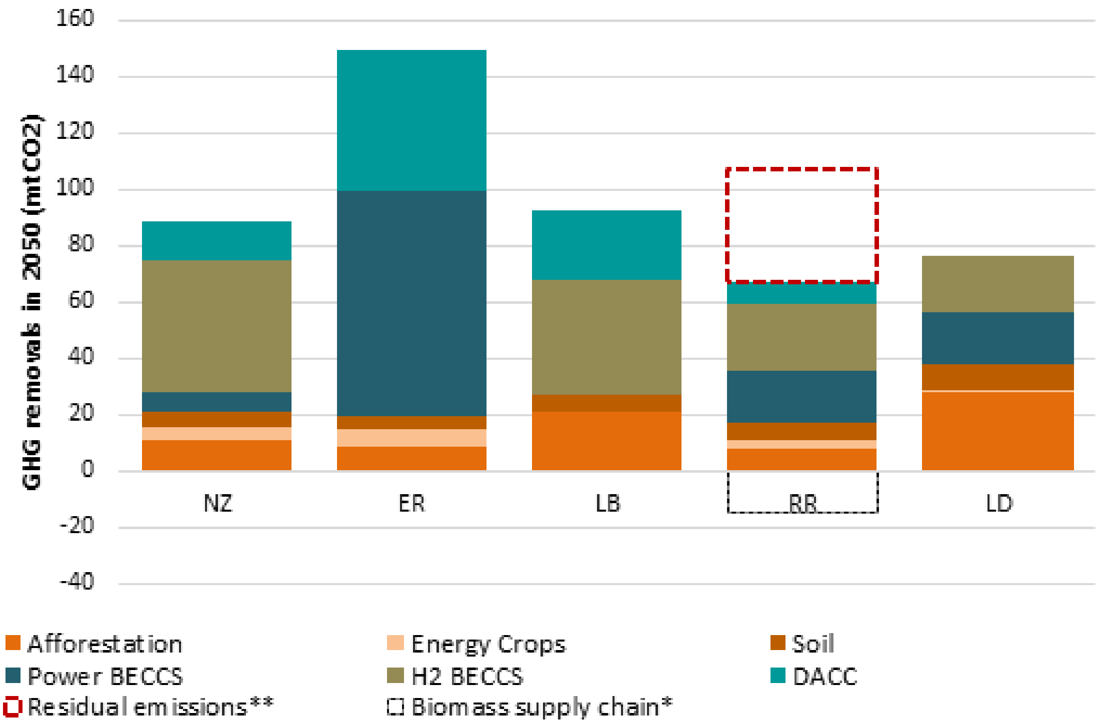
A scenario that depends on optimistic assumptions about CCS deployment and biomass availability comes with the significant risk that any delay or disruption may leave the net-zero target out of reach. On the CCS technology side, a lack of early support and of long-term investment for complex technologies and infrastructures could lead to much slower progress with engineered removals. On the biomass supply side, the high levels of demand assume that international markets for sustainable biomass will be both available and underpinned by credible regulations.

These risks are explored in more detail in the Low Biomass and Reduced Removals scenarios. Here, BECCS has a much smaller role, and removes no more than 40 $MtCO_2$/yr by 2050:

- *Reduced Removals* includes slower progress with CCS development through lack of early and long-term support and unsustainable biomass supply chains causing increased GHG emissions at all stages. Due to higher bioenergy supply chain emissions and slow CCS roll out, the *Reduced Removals* scenario fails to meet net zero in 2050, still having 40$MtCO_2$/yr remaining emissions.
- *Low Biomass* includes lower biomass supply to the UK, either due to increased international competition for a scarce resource, or through issues with sustainable supply chain development at home and abroad. Despite this restriction it reaches the net zero target in 2050.

Our fifth scenario includes a different view of the future. The *Low Demand* scenario includes quicker and more widespread deployment of energy-efficient technologies in the residential, industrial and service sectors. It includes deeper changes in diets that reduce the pressure on land requirements and emissions from the agricultural sector, freeing up land for deeper use of nature-based removal methods. It also covers reductions in car ownership, changes in travel patterns (e.g. with shifts from flying to train use) and a shift to a more circular economy. As a result, direct air capture is not utilised at all, and BECCS removes less than 40 $MtCO_2$/yr. Biomass is used both in power and hydrogen generation.

Figure 1 – Greenhouse gas removal deployment in 2050 in five scenarios



** While biomass supply chains are included in all scenarios, the Reduced Removals (RR) does not assume that biomass provided through these chains is carbon neutral. To do this a small emission factor is included on the supply chains in this scenario. This means that removals via BECCS are partly offset by these supply chain emissions.*
***Residual emissions highlight the missing amount of GHG removals that would be required to ensure that the RR scenario reaches the net zero emissions target in 2050.*

Taken together, the scenarios show the important implications that different assumptions about BECCS can have on the energy system and emissions. One further assumption is important to highlight: all scenarios assume that the effectiveness of carbon capture will increase over time. By 2050, between 95% and 99% of carbon emissions are captured by 2050. The final capture rate used depends on the sector, the technology and the scenario. While small, this increase can play an important role. In particular, it can shift the model's preference for using BECCS for power generation or for the production of hydrogen. Such a shift could be expected to have significant implications for the type and location of infrastructure investments required.

A policy framework for BECCS

Our analysis suggests that three important principles should underpin policies to support greenhouse gas removal in general, and BECCS in particular:

1. Government policies must prioritise actions to reduce emissions. The deployment of GGRs is not an alternative to emissions reduction.
2. Action to reduce emissions should include a major emphasis on reducing demand for energy and other products. This will increase flexibility in how the net-zero target can be met, and reduce the risks of relying on GGR measures that might not deliver what they promise. The Together for Climate Action campaign has published a separate explainer that sets out the energy efficiency opportunities that could help to deliver substantial reductions in demand.
3. Any GGR measures that are required are used to balance remaining emissions across the economy as a whole. They should not be used to achieve 'carbon neutrality' for sectors such as power or surface transport that can reduce emissions to zero. However, the power sector could act as a host for BECCS plants to help offset remaining emissions in other sectors such as aviation and agriculture.

With these principles in mind, our analysis also suggests five main policy actions to mitigate the risks associated with the deployment of BECCS. Where possible, we have specified which government departments should be primarily responsible for implementing them.

- First, reducing demand for energy and other resources through efficiency and a more circular economy will, in turn, reduce the amount of removals required. This includes action to reduce emissions from those sectors where remaining emissions are expected in 2050 (e.g. agriculture and air travel). This is a cross-government responsibility, and will require clear leadership from BEIS, Cabinet Office and Number 10.
- Second, policy incentives are required to support a diverse range of removal options. As the government has noted in the Net Zero Strategy, it could involve the reform of carbon pricing so that its scope is extended to removals. This will help to ensure that cheaper, less risky removal options, such as some forms of afforestation, are prioritised. This should be led by BEIS, working in close co-operation with Defra due to the strong overlap with land use and agriculture policies.
- Third, specific policies will be required to scale up engineered removal technologies including BECCS. Generic policies like carbon pricing are insufficient because these technologies are too capital-intensive and risky. This could be achieved through contracts for BECCS deployment, which should be implemented incrementally and cautiously. Large BECCS facilities on the scale of Drax should not be supported straight away. Pipeline networks and CO_2 storage reservoirs should have a large enough capacity for use by multiple plants, and to allow for rapid scale up if required. These policies should be led by BEIS, and will require strong buy-in from HM Treasury because of the need to set up new policy mechanisms that have budgetary implications.
- Fourth, policy support for BECCS should be conditional, and subject to rigorous evaluation and performance review. This will allow costs, technical performance, life cycle emissions and sustainability to be assessed before scaling up further. If BECCS is not delivering removals effectively, the government should increase efforts to reduce residual emissions and shift support for greenhouse

gas removals to other options. BEIS should also lead on the evaluation of BECCS performance. Ideally, this would be part of a more general strengthening of the evaluation and adjustment of innovation programmes as they are implemented.
- Fifth, regulations for biomass sustainability need to be reformed and extended to cover the full supply chain, including biomass supply, energy production, and the capture of CO_2 for use or storage. It is misleading to assume carbon neutrality at the point of combustion. This includes the alignment of regulations across borders to ensure a level playing field between UK and imported biomass, and the inclusion of changes to land use in carbon accounting rules. This should be led by Defra in conjunction with the Department for International Trade. New trade agreements will need to reflect environmental regulations such as this.

What is stopping this policy framework being implemented?

There are five key barriers to further action to the deployment of BECCS in a careful, sustainable manner:

1. **The lack of a holistic approach to innovation.** The government's current approach to greenhouse gas removals focuses mainly on so-called 'supply push' innovation – supporting R&D and small-scale demonstrations. But this neglects the larger scale financing and market creation policies needed to 'pull' innovations through from demonstration stage, and support rapid deployment at scale. In some other areas such as power and road transport, a more holistic approach is already being implemented. As the Net Zero Strategy acknowledges, this now needs to be extended to other sectors including GHG removals.
2. As the Climate Change Committee has noted in its assessment of the Net Zero Strategy, **the UK lacks an integrated strategy for the use of land**, including for agriculture, energy and ecosystem services. This is acting as a barrier to the sustainable use of land, including for land-based methods of GHG removal such as afforestation.
3. **Lack of market demand for negative emissions.** Market creation policies to support BECCS and other GGRs are missing. The incentives for carbon removal via BECCS and other engineered approaches are particularly weak. This exacerbates the financial risks that developers will need to take to deploy BECCS at scale.
4. **Lack of agility in the governance of new innovations.** There is a clear need to ensure that BECCS scale up is closely monitored. Government needs to be prepared to change course if results are not in line with GHG emissions reductions required, and to stop support if it fails. Without clear processes for this flexibility, which is challenging for government, there is a high risk of lock-in to solutions that are counter-productive.
5. **Partially developed regulation of biomass supply chains.** The UK has a basis for biomass supply chain regulation, and has applied this to some extent through existing support schemes. For instance, the Renewable Transport Fuel Obligation, which covers the use of biofuels in transport fuels, includes some key sustainability rules related to land use. But these rules only partially address social and wider environmental issues. The scope of these regulations needs to expand – including the tricky issue of aligning regulations across international borders. The latter will not be easy, especially in the current circumstances where there is pressure to agree trade deals that do not include strong environmental regulations.

Timeline of actions to 2050

Our policy recommendations imply the following timeline of actions for a careful scale-up of BECCS between now and 2050. We have placed particular emphasis on the 2020s since initial deployment is required to understand how much negative emissions BECCS can deliver in practice.

Short term: before 2025
- Substantial results published from BEIS and UKRI small-scale demonstrations of GGRs; re-evaluation of BECCS potential and risks based on these demonstrations

- Full plans for next-stage scale up of BECCS, with funding in place and arrangements for evaluation and monitoring
- Fully developed policy incentives for GGRs in general and BECCS in particular. Early action to support lower risk GGRs (e.g. afforestation)
- Revised and expanded regulations for biomass supply chains in the UK implemented
- Significant progress in negotiating international standards and monitoring arrangements for biomass supply chains

Medium term: between 2025 and 2030
- Development of first CO_2 pipeline and storage networks to support CCS clusters; with first CCS plants operational at industrial clusters
- First 'mid-scale' BECCS plants in operation with full monitoring (mid-scale could be in the 100-300MW range or equivalent)
- Agreement of international standards for monitoring biomass supply chain emissions with key trading partners

Long term: after 2030
- Continued expansion of lower risk GGRs with monitoring to ensure that removals are delivered whilst also strengthening other environmental services, including biodiversity
- Subject to clear evidence of sufficient net GHG removals, development of first full-scale BECCS plants followed by more widespread deployment

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Key references for further information

BEIS (2020). Greenhouse gas removals: call for evidence. Published on 4th of December 2020. https://www.gov.uk/government/consultations/greenhouse-gas-removals-call-for-evidence

HM Government (2021) Net Zero Strategy: Build Back Greener. HM Government. https://www.gov.uk/government/publications/net-zero-strategy

Royal Society and Royal Academy of Engineering. (2018). Greenhouse Gas Removal. Report by the UK Royal Society and Royal Academy of Engineering. royalsociety.org/greenhouse-gas-removal raeng.org.uk/greenhousegasremoval

Watson, J, Broad, O and Butnar, I (2021) The role of bioenergy with carbon capture and storage in the UK's net-zero pathway. Research Report. London: UCL Institute of Sustainable Resources

Can BECCS help us get to net zero? https://www.ucl.ac.uk/bartlett/news/2021/jul/can-beccs-help-us-get-net-zero

Energy efficiency – the first fuel https://www.ucl.ac.uk/bartlett/news/2021/aug/energy-efficiency-first-fuel