



Governing Carbon Dioxide Removal in the UK: Lessons Learned and Challenges Ahead

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This Policy Brief reviews the experience of the UK in developing principles for the governance of carbon dioxide removal (CDR) at scale. Early discussions on CDR governance took place in two separate and somewhat disjointed policy domains: forestry, on the one hand, and R&D support for novel “geoengineering” technologies, on the other. The adoption by the UK government of a 2050 “net zero” target is forcing an integration of these disparate perspectives, and should lead to a more explicit articulation of the role CDR is expected to play in UK climate strategy. This need for clarification is revealing some of underlying tensions and divisions in public views on CDR, particularly when it comes to forms of capture and sequestration deemed to be “non-natural.” We propose some principles to ensure that the development and deployment of carbon dioxide removal at scale strengthens a commitment to ambitious climate change mitigation and can thus enjoy broad public support.

Keywords: carbon dioxide removal, governance, net zero, negative emission technologies, geoengineering

INTRODUCTION

Over the last decade, the UK has taken steps to develop technological options for the removal of carbon dioxide from the atmosphere. This component in UK climate strategy has gained relevance and urgency with the adoption by the UK government in 2019 of a legal commitment to bring all UK-based greenhouse gas emissions to “net zero” by 2050. The new policy context demands greater clarity in the role that carbon dioxide removal (CDR) is expected to play in UK climate action, and creates an opportunity to develop a CDR governance system with broad public legitimacy.

Action toward CDR at scale in the UK must be seen in the context of a relatively consensual climate policy. The Climate Change Act 2008 established an ambitious goal for the reduction of greenhouse gas emissions (80% of 1990 levels by 2050), and created a set of institutions, most notably the Committee on Climate Change, tasked with monitoring progress toward that target. The Climate Change Act also set a series of recurrent obligations on the UK government, including the publication of an annual statement of UK emissions, the setting of five-yearly interim limits to emissions on the path to 2050 (“carbon budgets”), and a report every five years of its plans and policies to achieve those carbon budgets.

The Climate Change Act included greenhouse gas removals (GGR) under its remit, specifically removals “due to land use, land-use change or forestry activities in the United Kingdom.” At the

time, this implied an almost complete overlap between CDR and forestry policy. Traditionally UK forestry policy has been oriented toward biodiversity preservation and what the Independent Panel on Forestry described as the UK's distinctive “woodland culture,” but it has progressively been reframed as a key component in the country's climate change mitigation efforts. Since 2011, the Woodland Carbon Code has provided an incentive to preserve or expand woodland through the issuance of carbon credits, which can be sold to the government at a guaranteed price every five or 10 years, or used to compensate for UK-based greenhouse gas emissions. Under the Environmental Land Management schemes (ELMs) that will replace the support programmes of the EU's Common Agricultural Policy, the capacity of agricultural and forest management practices to sequester carbon will be a key metric guiding “landscape-scale land use changes” in the UK (DEFRA, 2020).

In parallel to this strand of policy development, public debate on CDR governance in the UK began to crystallize in the late 2000s in the context of R&D policy, specifically around the question of whether to incentivize the development of novel forms of “climate engineering.” It was in this context that governance principles for large-scale CDR were first developed, in conjunction with the scientific assessments of largely untested technological options and social-scientific research into emerging public opinion on “geoengineering.”

CDR GOVERNANCE IN THE CONTEXT OF R&D POLICY

The landmark 2009 Royal Society report *Geoengineering the Climate: Science, Governance and Uncertainty* considered several forms of large-scale carbon dioxide removal (including land use and afforestation) alongside techniques for solar radiation management (SRM). The report noted that “the greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance, rather than scientific and technical issues” (Royal Society, 2009, p. xi). It recommended a 10-year government-funded research programme to explore different technical options, and called for an international code of practice to govern this research, noting that “perception of the risks involved, levels of trust in those undertaking research or implementation, and the transparency of actions, purposes and vested interests, will determine the political feasibility of geoengineering” (Royal Society, 2009, p. xii). In the wake of the report, research funding bodies launched several initiatives in this area, supporting both technical assessments of different kinds of geoengineering and an embryonic public debate over their desirability. The 2010 *Experiment Earth?*, a public dialogue sponsored by the Natural Environment Research Council (NERC), included specific discussions on afforestation, biochar, ocean liming, ocean iron fertilization and direct air capture (a decade later, Climate Assembly UK would revisit these and other forms of CDR as part of its remit).

The understanding of large-scale CDR as a form of geoengineering framed the problem as one of regulating

emerging, often speculative technologies. It lumped together highly heterogeneous modalities of intervention—from peatland conservation to stratospheric aerosol injection—and yielded governance principles focused on the criteria for responsible research and development of climate engineering options (Royal Society, 2009; Rayner et al., 2013; Stilgoe et al., 2013). Formal deliberation exercises like those conducted under *Experiment Earth?*, and social scientific research on the public acceptability of CDR at scale, emphasized concerns over mitigation deterrence, and revealed a sharp distinction in public opinion between those removal options that were perceived to be “natural” and offer significant environmental co-benefits (e.g., enhancing the storage of carbon in soils, peatland and wetland preservation, better forest management), and those seen as “artificial” or “engineered” (Corner et al., 2013; McLaren, 2016; see also Bellamy and Lezaun, 2017).

During the 2010s, the assessment of CDR options was progressively decoupled from solar radiation management, becoming increasingly conceptualized as the development of a set of novel “negative emissions technologies.” This coincided with the greater relevance of CDR in IPCC mitigation scenarios, and the commitment, expressed in the Paris Agreement, to balancing greenhouse gas emission sources and sinks in the second half of the century (Anderson and Peters, 2016; see also Bellamy and Healey, 2018). In the UK, the first publicly-funded R&D initiative dedicated exclusively to CDR was the 2017–2021 Greenhouse Gas Removal from the Atmosphere programme. Funded jointly by the UK Research Councils and Government, the programme assessed the “real world” feasibility of greenhouse gas removal techniques, and sought to synthesize scientific and technical knowledge for use by national and international policymakers. It funded university-based research only, and evaluated a variety of CDR options, including agroforestry, bioenergy with carbon capture and storage (BECCS), soil sequestration, biochar, and enhanced rock weathering. Notably, it did not include any direct air capture (DAC) projects.

Governmental support for university-based R&D activities coincided with the development of CDR capabilities by some UK corporations. The most notable example, in terms of potential scale and stage of development, is Drax, the UK's largest thermal power station, which in 2019 began trialing carbon capture on its biomass-fired unit in North Yorkshire. A field of start-ups and small-scale enterprises began to explore and advocate for several technologies of carbon dioxide removal, particularly DAC. In 2019, the Committee on Climate Change called on the Government to expand support for early-stage research and demonstration projects, and to clarify the governance rules and market mechanisms that would ensure payment for removals, in order to create a set of signals that would allow companies and economic sectors to invest in the development of CDR at scale (Committee on Climate Change, 2019).

The first part of this recommendation has been addressed with the recent establishment of five Greenhouse Gas Removal Technology Demonstrators. Funded by UK Research and Innovation (the public body created by the merger of several research funding organizations) and scheduled to run from 2021 to 2025, the Demonstrators are expected to advance

the “technology readiness” of CDR options. The selected projects are oriented primarily toward biological forms of carbon capture: accelerated peat formation, assessing the most effective species and locations for carbon sequestration through afforestation, biochar, perennial bioenergy crops, and enhanced rock weathering in farmland. In addition to the five Demonstrators, UKRI is funding a GGR Directorate Hub, charged with conducting cross-cutting research and exploring the economic, social and legal conditions for a scaled-up deployment of these and other GGR options.

Demonstrators and Hub carry the legacies of the UK approach to CDR governance in the context of R&D policy: an emphasis of interdisciplinary research (including social-scientific research on public perceptions), a commitment to the principles of Responsible Research and Innovation, and the design of processes of stakeholder engagement to assess the real-world acceptability of the proposed forms of removal. These tools are useful to create a more robust assessment frameworks for pilot projects, but it is remarkable how embryonic and “early stage” the field of CDR remains more than a decade after the Royal Society *Geoengineering the Climate* report. In the meantime, the policy context has changed significantly, due to the continuing failure to curb global emissions and the international aims enshrined in the 2016 Paris Agreement. The result is a greater urgency to develop a clear set of expectations as to the role CDR at scale ought to play in UK climate action in the near future.

CDR GOVERNANCE AND NET ZERO UK 2050

In June 2019 the UK government adopted a legally binding commitment to reach “net zero” by 2050. While a specific plan outlining the role that greenhouse gas removals should play in UK climate strategy is still to be published at the time of writing, this policy target has increased the visibility of CDR in public debate.

Currently, the only policy domain with explicit targets is forestry. Tree planting became in fact a prominent campaign issue during the last UK general election, with political parties vying with one another to offer the most ambitious goal (the Conservatives pledged to plant 30 million trees a year by 2025, the Liberal Democrats committed to 60 million trees per year, Labor announced plans to plant 2 billion trees by 2040, and the Scottish Nationalist Party promised to plant 36 million trees in Scotland by 2030). Subsequently, the UK has adopted a target of 30,000 hectares of new woodland per year by the end of the current Parliament, and the government has defined tree planting as “a central pillar in the efforts to reach net zero emissions by 2050” (UK Government, 2021). That political parties see tree planting as a vote-winning issue underlines the evidence that this remains a popular “climate solution” in the UK, but the scale of afforestation implied by these pledges points to a clear potential for conflict with other environmental public goods. Announcing an ambitious target for tree planting or woodland expansion is much easier than making sure that the right tree is planted in the right place and for the right reasons (Broadmeadow,

2020). “Forests and better forest management” was by far the most popular form of greenhouse gas removal among participant in the 2020 Climate Assembly UK, but support was explicitly conditional on the capacity of this policy to deliver clear co-benefits (promotion of biodiversity, access to nature, prevention of erosion, etc.). Tree planting is also the preferred (often the only) form of carbon dioxide removal mentioned in corporate net zero pledges, but these commitments tend to include no details on the location, management, or species composition of the new plantations, nor of the criteria that will be used to ensure permanence of storage. If carbon capture becomes the preeminent consideration in forest management, it is possible that, under certain conditions, commercial afforestation might deliver better outcomes than woodland expansion (Forster et al., 2021).

In the meantime, other forms of CDR have shown a more controversial public profile. As part of its plans for a “green recovery” from the Covid-19 pandemic, the UK government recently announced a scaling up Carbon Capture and Storage (CCS) technologies, and the creation of a fund dedicated to promote Direct Air Capture. The DAC announcement received a great deal of attention in the media, where it was presented as the brainchild of a party-political advisor with a track-record for favoring technological solutions (newspapers reported skepticism about the initiative in government circles, and it is noteworthy that there was little if any analysis published justifying the size of the fund, in contrast to the systematic assessments that support funding for other areas of low-carbon innovation). Key environmental groups singled out the DAC announcement for criticism. “It’s a bit like sailing a ship toward an iceberg and the captain on the ship telling you not to worry about the iceberg as he would soon invent a machine that will help you fly. It’s ridiculous. We shouldn’t hope some magical solution will come in the future” (Head of Science, Friends of the Earth UK).

The debate over DAC suggests that support for large-scale CDR beyond expanded forms of “natural sequestration” is far from assured. Research on public perceptions of CDR in the UK suggests that industrial forms of carbon dioxide removal are often seen as “non-transition” technologies, that is, as incompatible or in conflict with prevailing visions of decarbonisation and sustainable development (Cox et al., 2020). Experimental research on the acceptability of CDR also indicates that public support may be contingent on the type of incentive used to promote its development (Bellamy et al., 2019). To some extent these concerns and apprehensions reflect the structure of public views on carbon capture and storage (CCS), where concerns over technical risk (e.g., leakage) and concerns over political risk (e.g., adoption of a technological solution to displace other, more acceptable methods of climate change mitigation) are often difficult if not impossible to disentangle (Thomas et al., 2018; see also Selma et al., 2014). The ambivalence and fluidity of public opinion on this matter is perhaps best grasped by analogy with evolving views of nuclear power in the context of the climate crisis. Studies of UK public attitudes describe a position of “reluctant acceptance” toward nuclear power when this form of energy generation is reframed as

an instrument of climate action (Bickerstaff et al., 2008), but also underline that this position is highly conditional, and only emerges when all other (preferred) mitigation options have been excluded (Pidgeon et al., 2008; Corner et al., 2011).

This suggests that public support for CDR at scale will hinge on whether its development takes place in the context of a climate change mitigation strategy that enjoys broad legitimacy. The Climate Change Committee has emphasized this point in its call for policies that “place GGRs in the context of a wider strategic approach to reaching Net Zero, setting out a plan for development and deployment of removals, but also for actions elsewhere to limit the need for them” (Climate Change Committee, 2021, p. 198). This is consistent with the “precautionary” approach that Greenpeace UK advocates in relation to CDR in companies’ climate plans. Such an approach, the campaign organization argues, “would put efforts into developing CDR technologies, while also cutting emissions at the level that would be needed assuming limited CDR availability” (Greenpeace UK, 2021).

Net zero provides a framework within which this set of issues, in particular the relationship between greenhouse gas removals and emissions reductions targets, can be made explicit and subjected to broad consultation. Some have argue for a clear separation of targets for removals and emissions reductions (McLaren et al., 2019) and a detailed specification of the relative role that removals are expected to play in achieving net zero targets (Rogelj et al., 2021). It might even be possible to develop taxonomies of removals that take into consideration whether they serve to enhance emissions reductions or simply remedy mitigation failures (Shue, 2021). Accepting that greater transparency and accountability are essential conditions for a national CDR governance system that can claim broad public legitimacy, we propose a set of recommendations tailored to current policy discussions in the UK.

ACTIONABLE RECOMMENDATIONS

Greater transparency and accountability should begin with the publication of the detailed mix of measures planned to achieve the UK 2050 net zero target, as required by the Climate Change Act. This would allow interested parties to understand what role this Government sees for specific CDR approaches. A detailed policy operationalization of the country’s commitment is now evidently urgent. As the Chair of the CCC’s Adaptation Committee, Baroness Brown, recently noted: “The UK is leading in diagnosis but lagging in policy and action” (Climate Change Committee, 2021).

The proposed measures should in fact aim to over-deliver on the net zero objective, given the range of risks that might limit the availability of CDR options in the future. Such over-delivery ought to apply to both emissions reduction measures and to the proposed targets for removals (Smith, 2021).

While creating different targets for emissions cuts and removals will reduce the risk of mitigation deterrence, the development of CDR at scale makes clear that these are not separate domains of climate action. In some cases, CDR systems may be used to produce alternatives to fossil fuels, or incorporate components, technologies and supply chains that are also involved in efforts to decarbonise key sectors of the economy. Given the untested nature of all large-scale CDR options currently under consideration, it may be appropriate to adjust targets to the respective maturity or readiness level of the technology in question, and to the concrete social and environmental context in which they are to be deployed (Smith, 2021).

An accountable strategy for reaching net zero by 2050 should also specify the carbon storage involved. This should be specified by type of storage (biological or geological), and include plans to monitor and manage it. Policy discussions have so far focused on the numbers of trees to be planted or the funding available to subsidize new forms of CDR. The scope of the conversation needs to expand to include what will be done to ensure that carbon, once captured, is rendered inert. The greater the intended use of sinks, the greater the need for monitoring, and for plans to reduce and manage the risk of possible leakage.

There is, finally, a critical international dimension to all these questions. The burden of removing greenhouse gases from the atmosphere must be shared fairly and equitably across countries, and the terms of any scheme for the international trading of carbon credits will need to be defined accordingly (Allen et al., 2020). The UK should also lend its expertise to countries willing to consider CDR options in their respective national climate strategies, for example by contributing to the development of internationally acceptable standards for the measurement, reporting and verification of removals (Healey et al., 2021). Cooperation toward this end would fall squarely within the activities for climate technology transfer and capacity building programs supported by UK International Climate Finance [UK Department for Business, Energy and Industrial Strategy (BEIS), 2019].

CONCLUSION

Although UK climate policy remains relatively consensual (at least in comparison to other countries), the prospect of developing CDR at scale is revealing some underlying tensions. While “natural” forms of carbon removal and sequestration are *a priori* popular, what counts as “natural” becomes contested as soon as specific interventions are proposed, particularly when the scale of sequestration must compensate for the ongoing failure to reduce greenhouse gas emissions in line with Paris Agreement obligations. On the other hand, evidence from public debate and social-scientific research on public perceptions suggests that forms of CDR perceived to be “industrial” or “engineered” and/or involve significant alterations in natural systems remain

controversial, their “political feasibility” contingent on whether they are seen to enhance, rather than impede, the transition toward a low-carbon economy. Net zero provides an opportunity to bring transparency and accountability to these issues by making explicit the role that large-scale CDR is expected to play in UK climate policy, and subjecting those terms to extensive public debate. Fulfilling this opportunity requires consensus on the definition of “net zero,” and a governance framework capable of ensuring that the deployment of CDR at scale is aligned with the pursuit of a broad range of public goods.

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All authors contributed to the article and approved the submitted version.

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Conflict of Interest: TK is Founder and CTO of a company developing direct CO₂ air capture.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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