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What role can negative emissions technologies play in Net Zero Britain?

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The Tyndall Centre for Climate Change Research at the University of East Anglia and University of Manchester has an active research group on Greenhouse Gas Removals. We are submitting evidence from our recently funded research projects including; NERC-funded Feasibility of Afforestation and BECCS for Greenhouse Gas Removal (FAB-GGR)(NE/P019951/1, 2018-2022) - a consortium project led by University of East Anglia with University of Manchester, University of Exeter, University of Aberdeen and Aston University; the EPSRC-funded Supergen Bioenergy Hub (EP/S000771/1, 2018-2022) and a University of Manchester PhD studentship (2019-2022).

What contribution could NETs (through DACCS, BECCS, and/or other NETs) make to achieving net zero by 2050?

For NETs to contribute to net zero it needs to be within a comprehensive Net Zero Strategy **across all government departments** and **all** policies to mitigate as close to zero as possible. Analysis by the National Audit Committee identifies cross-department collaboration, accountability and prioritisation to be a key challenge and potential risk (NAC, 2020). The life cycle emissions across the entire NET supply chain must be assessed to ensure CO_2 removal from the atmosphere.

In the UK, BECCS (and DACS) could contribute to achieving net zero by (i) offsetting difficult-to-decarbonise sectors in the economy (aviation, heavy industry and non-CO_2 emission from agriculture) and/or (ii) by enabling the UK to go beyond net zero (i.e .to become net negative).

The specific combination of BECCS and DACS in place by 2050 will depend upon the details of the policy mechanisms to support sustainable domestic (and possibly imported) biomass sources as well as *how* the energy, transport and industrial sectors decarbonise. It is essential that the full life cycle emissions of BECCS supply chains are assessed, particularly the biomass feedstock source. If direct or indirect land use change occurs (e.g., deforestation) to grow bioenergy crops then the total amount of CO_2 removed by the BECCS supply chain is significantly reduced (Harper et al, 2018; Vaughan et al, 2018). Scaling up is likely to entail a mix of different BECCS supply chains (i.e., different biomass feedstocks - waste, agricultural residues, dedicated bioenergy crops - combined with different energy conversion processes - electricity, hydrogen, heat) rather than a simple multiplier of one supply chain, such as Drax (Garcia Freites et al, 2021; Clery et al, 2021). Spatial analysis of possible BECCS sites in the UK indicates that transport between where biomass is grown and where it is used (e.g., distance between farms and power plants) has a large impact on cost and carbon efficiency of BECCS supply chains (Donnison et al, 2020; Freer et al, 2021). Access to geological storage sites and decarbonisation of the industrial clusters, including the use of CCS in energy intensive industries (e.g., iron and steel, chemical processing) will drive the location of CCS transport and storage infrastructure. This in turn will shape the geography of both BECCS and DACS development, which both depend on access to CO_2 transport and storage infrastructure.

Which 'hard to decarbonise' sectors could benefit most from NETs, and which should be prioritised?

There are two ways in which NETS could benefit 'hard to abate' sectors:

1. Technical opportunities for use of BECCS within certain industrial processes (for example steel production)
2. To 'remove' emissions that cannot be reduced or avoided

The potential for NETs applications in the UK will be subject to both biophysical and non-technical limitations which will ultimately restrict the scale at which they can be used, therefore careful consideration and a strategic, coordinated approach to the use of emissions offsetting is essential. Care should be taken to avoid 'unplanned substitution' (BEIS Greenhouse Gas Removals, Summary of Responses to the Call for Evidence) as a result of voluntary offsetting. This should incorporate a full life cycle approach across the economy which recognises that all sectors will have a 'hard-to-abate' element. Given the costs and limitations of NETs, fairness, transparency and a whole economy perspective is needed to ensure NETs are prioritised appropriately. The risk is that certain sectors or industries lower their mitigation ambition and use NETs to continue with high emitting activities.

At what technological stage are current NETs, and what is the likely timeframe that will allow NETs to be operational at scale in the UK?

Land-based NETs, afforestation, agroforestry, soil carbon sequestration, habitat restoration are all available today and require supporting policies and incentives to scale up in the UK, recognising the multiple benefits which these approaches bring.

Not all the component parts for a full BECCS supply chain are available for immediate deployment in the UK; BECCS depends on having CCS infrastructure in place. Optimising the location and configuration of BECCS supply chains could have a significant impact on the carbon removal performance (Freer et al, 2021). There are a variety of BECCS supply chains configurations at different stages of technology readiness (TRL). Supply chains with potential higher efficiencies (e.g., gasification) are at lower TRLs (Garcia Freites et al, 2021).

What are, and have been, the barriers to further development of NETs? How can such barriers be overcome?

Land availability, including suitability, ownership and competition with other uses, is a dominant barrier to deployment for BECCS, afforestation and other land-based NETs. Other barriers to deployment include political leadership, effective policy to incentivise NETs and lack of consideration of fairness and competing human needs in current decision-making processes (Forster et al, 2020; Waller et al, 2020; Clery et al, 2021).

Non-technical barriers such as political appetite for NETs and using effective policy to incentivise NETs are going to be critical to the deployment of NETs (Forster et al, 2020; Waller et al, 2020; Clery et al, 2021). For NETs deployment to be effective and sustainable, explicit consideration of the social, political and equity issues (e.g., justice and ethics, social trade-offs and implications, competing human needs and values, leadership and political will) is essential. Our analysis found that these dimensions are routinely excluded from climate assessments and thus decision-making processes - and as a result can be considered current constraints to fair and equitable deployment of these technologies (Forster et al., 2020, Gough & Mander, 2019).

With the net zero framing and the refocus and redesign of agricultural and farming policies post Brexit, the policy landscape relating to land use and land-based solutions has become increasingly complex. Multiple initiatives and overlapping policy frameworks which impact on land-based carbon removal potential present a challenge to delivering a clear coordinated strategy which can deliver quantifiable, verified carbon removal.

What are the trade-offs between availability of land and availability of sustainable biomass to make NETs a viable option in and beyond the UK?

As bioenergy is increasingly included within energy strategies the scale of biomass resources required to balance future fuel demands will also increase. Where strategies are developed on use of dedicated energy crops, this may also increase pressure on land. Risk of detrimental sustainability impacts linked to bioenergy may also grow as the scale of resource production/ collection/ harvesting/ mobilisation increases. These risks may be intensified further as some of the regions with the greatest biomass demands have comparatively low resource availability, and trends towards longer more complex international supply chains can already be observed (Welfle, 2017). These sustainability risks have the potential to be exasperated by the growing distances between the resources and supply chains, and the feedstock purchasers and bioenergy plant operators (Welfle et al, 2020; Röder et al, 2019).

Dedicated biomass and energy crop resources grown on UK lands are identified in many studies as providing a valuable potential opportunity for the future UK bioenergy sector. Studies such as Welfle et al (2014) identified that UK lands could provide >31 Mt of grown resource for the sector by 2050 (Welfle, et al 2014). The standout driver influencing the availability of these resources was identified as the utilisation of available lands dedicated for its growth. The analysis also highlighted that this resource opportunity is highly underutilised - concerted efforts are required to incentivise and reduce the barriers preventing use of lands for biomass production.

The primary sustainability risks for bioenergy as identified by the European Commission when developing the sustainability framework of REDII were: i) biogenic CO_2 and supply chain emissions, ii) impacts on biodiversity, soil and air quality, iii) efficiency of installations, and iv) administrative burden costs (European Commission, 2016). A range of methods and approaches have been developed to regulate, assess and monitor bioenergy sustainability performances. However, legislation focuses heavily on issues of GHG emissions savings, and protection of land biodiversity and carbon sinks - all vital sustainability issues. Current research by the UK Supergen Bioenergy Hub identifies that sustainability of bioenergy covers far more issues than those targeted within legislation – where land, carbon and biodiversity are prioritised. Legislation focuses on preventing the perceived greatest risks. However, it is within many of the wider sustainability themes where bioenergy can provide the greatest benefits - jobs, infrastructure, ecosystem services, products for the bioeconomy, economic stimulation for wider sectors etc. There is therefore also a strong argument to also develop frameworks to maximise benefits gained (Welfle & Röder, *in review*).

Globally there are increasing pressures on the availability of land for the production of biomass due to an increasing requirement for agricultural land to support growing populations and the need to conserve forests and the ecosystem services they provide. Sustainable biomass production includes the conservation of forests, so options for increasing available land globally lie mostly within the food system. Land can be freed from the food-system through intensification of pasture, closing crop yield-gaps, reducing wasted food, or reducing animal product consumption, especially ruminants (Ball et al, *in review*).

What other drawbacks for the environment and society would need to be overcome to make NETs operational?

Our research suggests that a responsible development approach would explicitly take account of social and political dimensions, and wider trade-offs associated with NETs, systematically as part of any appraisal or feasibility assessment, not as a separate 'add-on' to a technical or narrow 'public acceptability' framing (Gough & Mander, 2019; Waller et al, 2020). To date, evidence for the feasibility of GGRs is largely provided by techno-economic expertise. Our research suggests that limited public engagement with GGRs may not necessarily represent only a lack of public awareness but can also plausibly reflect decisions of concerned groups to disengage from debates framing GGRs as solutions to climate change (Waller et al, 2020). There is a strong policy distinction between 'engineered' (i.e. BECCS) and 'natural' or land-based NETs (i.e. afforestation) but our analysis finds this distinction is used more flexibly in practice and does not map neatly onto public and other stakeholder engagement with BECCS and afforestation (Waller et al, 2021).

Environmental and social 'drawbacks' will be highly case specific - depending upon what is deployed and how deployment is managed and governed. This includes the supply chain configuration, scale, locational and siting issues and as well as wider issues relating to justice. These issues should be understood and accommodated within the planning, incentivisation and regulation of NETs as they are deployed and the industry expansion.

Given the proposed role of NETs in climate change modelling, is there a danger of over-reliance on these technologies in net zero strategies?

There is a danger of over-reliance on these technologies in net zero strategies as the oversimplification necessary to represent NETs in future scenarios cannot capture well the complexity, interconnections and broader objectives that may limit the development of NETs. Social and political factors are important but poorly represented by these models of global economy and energy system (Forster et al, 2020). For example, within a model, forests can be protected, but in the real world this is harder to ensure, requiring strong environmental governance in the country growing the biomass (Vaughan et al, 2018; Forster et al, 2020). If bioenergy expansion drives deforestation directly or indirectly then the amount of carbon removed by a BECCS supply chain is significantly reduced (due to carbon emissions from the deforestation). Land-based NETs, i.e., soil carbon sequestration, provide benefits beyond just cost and carbon (e.g. improved food security, reduced land degradation) tend to be poorly represented in these models.

The models that generate future emission scenarios are useful but should be used together with other sources of information - particularly those that provide insights on the social and political feasibility of NETs (Forster et al, 2020; Waller et al, 2020).

How should the UK Government support the further development of NETs?

We identify 5 ways to support the further development of NETs.

- Ensure suitable monitoring, reporting and verification mechanisms are in place to deliver sustainable biomass (for use in BECCS) (Forster et al, 2020; Clery et al, 2021).
- Design policy mechanisms that take into account the full life cycle emissions of NETs and incentivise those that deliver carbon removal (Garcia Freites et al, 2020; Clery et al, 2021).
- Evaluate NETs against broader metrics than just cost and carbon. The co-benefits of different NETs may provide development and deployment opportunities as well as potential compromises (Forster et al, 2020). Consideration of co-benefits may align better with broader societal objectives (e.g., biodiversity, health and well-being).
- Be cautious about the distinction between ‘engineered’ and ‘natural’ NETs as there are direct overlaps (e.g., forestry and agricultural residues) (Vaughan et al, 2018). Public and other stakeholder engagement with the two types is more flexible than the current policy framing (Waller et al, 2021).
- Defining the role of NETs in wider decarbonisation efforts through a coordinated strategy will limit the risks of over-reliance on NETs and any unwanted emissions reduction inaction.

The Government has indicated it will publish a Biomass Strategy in 2022, including the role of BECCS. What should be included in this strategy?

Research carried out by the UK Supergen Bioenergy Hub in collaboration with BEIS and DfT identified the following key issues that should be included in the upcoming UK Bioenergy Strategy (Welfle, Holland, Donnision, Thornley, 2020):

- Incorporate natural capital and ecosystem services perspectives within UK bioenergy resource models and future scenarios.
- Strategy to engage with the human actors that are essential to the success of the future UK bioenergy sector. For example, with landowners/ managers who will be key for the increased production of dedicated biomass resource for energy in the future.
- Analysis of the future dynamics of the bioenergy sector and biomass resources. Mapping how use of biomass resources may evolve over short, medium and long timeframes, and the forms of bioenergy that will be required as other renewable/ legacy energy technologies change over timeframes.
- Vital to ensure there is a cross-Government department bioenergy strategy, working together to promote resource production/ mobilisation and bioenergy generation.

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References

Ball et al (*in review*) C-LLAMA v1.0: traceable model for food, agriculture and land-use. *Geoscientific Model Development Discussions [preprint]* https://doi.org/10.5194/gmd-2021-169

Clery et al (2021) Bringing greenhouse gas removal down to earth: Stakeholder supply chain appraisals reveal complex challenges. *Global Environmental Change* https://doi.org/10.1016/j.gloenvcha.2021.102369

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

European Commission (2016) Commission Staff Working Document: Impact Assessment - Sustainability of Bioenergy. Brussels, 2016. https://ec.europa.eu/%0Aenergy/sites/ener/fles/documents/1_en_impact_assessment_part4_%0Av4_418.pdf.
Forster et al (2020) Mapping feasibilities of greenhouse gas removal: Key issues, gaps and opening up assessments. *Global Environmental Change* https://doi.org/10.1016/j.gloenvcha.2020.102073
Freer et al (2021) Carbon optimal bioenergy with carbon capture and storage supply chain modelling: How far is too far? *Sustainable Energy Technologies and Assessments* https://doi.org/10.1016/j.seta.2021.101406
Garcia Freites et al (2021) The greenhouse gas removal potential of bioenergy with carbon capture and storage (BECCS) to support the UK's net-zero emission target. *Biomass and Bioenergy* https://doi.org/10.1016/j.biombioe.2021.106164
Gough & Mander (2019) Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS. *Current Sustainable/Renewable Energy Reports* https://doi.org/10.1007/s40518-019-00137-0
Harper et al (2018) Land-use emissions play a critical role in land-based mitigation for Paris climate targets. *Nature Communications* https://doi.org/10.1038/s41467-018-05340-z
Röder et al (2019) Understanding the timing and variation of greenhouse gas emissions of forest bioenergy systems. *Biomass and Bioenergy* https://doi.org/10.1016/J.BIOMBIOE.2018.12.019
National Audit Committee (2020) Achieving Net Zero. https://www.nao.org.uk/report/achieving-net-zero/
Vaughan et al (2018) Evaluating the use of biomass energy with carbon capture and storage in low emission scenarios. *Environmental Research Letters* https://doi.org/10.1088/1748-9326/aaaa02
Waller et al (2020) Contested framings of greenhouse gas removal and its feasibility: social and political dimensions. *WIRES Climate Change* https://doi.org/10.1002/wcc.649
Waller et al (2021) Searching for a public in controversies over carbon dioxide removal: an issue mapping *Science, Technology & Human Values* https://doi.org/10.1177/01622439211043568
Welfle et al (2014) Increasing biomass resource availability through supply chain analysis. *Biomass and Bioenergy* https://doi.org/10.1016/j.biombioe.2014.08.001
Welfle (2017) Balancing growing global bioenergy resource demands - Brazil's biomass potential and the availability of resource for trade. *Biomass and Bioenergy* https://doi.org/10.1016/j.biombioe.2017.06.011
Welfle et al (2020) Accounting Whole Life Cycle Bioenergy Emissions within the UNFCCC Emission Accounting Framework. Supergen Bioenergy Hub, 2020. https://www.supergen-bioenergy.net/wp-content/uploads/2020/06/Accounting-whole-life-cycle-bioenergy-emissions-within-the-UNFCCC-emission-accounting-framework_1-June-2020.pdf.
Welfle, Holland, Donnison, Thornley (2020) UK Biomass Availability Modelling. *Scoping Report for BEIS & DfT.* UK Supergen Bioenergy Hub, 2020.
Welfle & Röder (*in review*) Mapping the Sustainability of Bioenergy to Maximise Benefits, Mitigate Risks and Drive Progress toward the Sustainable Development Goals. *Global Environmental Change*.