Implications for UK Net Zero of Bioenergy with Carbon Capture and Storage (BECCS) Utilising Southern US Sourced Biomass

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Summary

- **This study finds that a UK BECCS system, based on wood pellets supplied by Drax pellet mills in the Southern US, would increase rather than decrease levels of atmospheric CO_2e compared to a scenario without the BECCS system, until approximately 2053.**
- Bioenergy with carbon capture and storage (BECCS) is a prominent carbon removal technology in mainstream climate modelling, assumed to produce negative emissions by capturing and storing CO_2 released when wood is combusted.
- This analysis seeks to explore if a UK BECCS plant (such as that proposed by Drax Group) would in fact contribute to meeting the UK's Paris Agreement commitments and 2050 Net Zero target. It compares the BECCS pathway with a counterfactual scenario without the BECCS plant, with foregone electricity provided from elsewhere in the grid.
- The analysis is based on an updated version of a consequential life cycle assessment (cLCA) for a UK bioenergy plant where wood pellets are sourced from three Drax-owned mills in the Southern US and combusted for electricity in the UK (Buchholz et al., 2021).
- The original cLCA showed that the demand for wood pellets induced by the UK biomass plant led to reduced forest carbon stocks in managed pine forests in Louisiana and Mississippi for at least 40 years compared to the baseline scenario. This led to more CO_2 in the atmosphere in the bioenergy scenario compared to the non-bioenergy 'baseline' scenario, even when the emissions from the alternative UK power generation to replace the bioenergy power station are included.
- The updated analysis assesses the result of CCS technology becoming fully operational at the UK bioenergy power station from 2030, with a 90% capture rate.
- Results indicate that the proposed UK BECCS system would not produce additional negative emissions until approximately 2053, compared to the baseline no-BECCS scenario.
- The additional atmospheric CO_2e levels resulting from the BECCS scenario are due to the more intensive forest management regime associated with additional wood pellet demand to feed the BECCS plant.
- The results demonstrate that the CCS technology itself is less important than the impact of wood pellet sourcing on forest carbon stocks and flows.
- The analysis demonstrates the importance for policymaking of cLCAs which address the full value chain of emissions and sequestration compared to realistic counterfactual scenarios – i.e. what would have happened in the absence of the intervention.
- While current accounting regimes in the UK would still attribute negative emissions to the BECCS scenario, this does not reflect the real impact on the atmosphere, where the BECCS scenario worsens climate change compared to the baseline.
- Updates to policy and accounting regimes to reflect the full accounting of greenhouse gas removals and emissions, compared to counterfactuals, could, therefore, substantially undermine the case for investment in BECCS.
- This approach is consistent with the Greenhouse Gas (GHG) Protocol's pilot Land Sector and Removals Guidance (2022) developed by the World Resources Institute and World Business Council for Sustainable Development, which states that businesses should consider "avoided removals (removals that would have otherwise happened, but that, as a result of a company's activities, did not happen)," and "assess the GHG impacts of an action compared to the conditions most likely to occur in the absence of the action. Companies should use the results to ensure that actions lead to global net GHG benefits."

Context

Increasing demand for woody biomass-derived electricity has resulted in a rapidly expanding wood pellet industry in the Southern US. The largest export market for US wood pellets is the UK (approximately 70% for 2023; USDA, 2024). Between 2013 and 2018, Drax Power, a UK based utility and a primary consumer of US wood pellets, converted four of its former coal units to burn wood and has received significant climate-policy derived subsidies in the UK (in the range of £6 billion since 2012) (Drax Group, 2023).

Since this demand for electricity from woody biomass is driven by the objective to lower greenhouse gas (GHG) emissions from the UK electricity sector, it is crucial to understand the full carbon consequences of the harvesting of wood pellets from forests. Substantial contributors are often missed in accounting, for example the impact on forest sequestration and derived wood products. In the UN/IPCC accounting framework (Garg and Weitz, 2019), the carbon stock changes in forests as a result of harvesting wood for bioenergy should be accounted in the land use sector of the country of origin. However, impacts on forest carbon stocks are not reflected by the UK utility burning the wood pellets, nor considered in the policy design of UK climate incentives. Even allowing for a sourcing criterion of stable or increasing forest carbon stocks of the harvest area, a crucial overlooked factor includes the potential carbon sequestration from forest growth that would have occurred in the absence of harvesting for wood pellets.

Drax's own Independent Advisory Board published recommendations on Drax's carbon accounting narrative (Drax, 2022), calling on the company to:

- "Ensure the narrative is region specific and includes counterfactuals"
- "Employ more methodologies, such as statistical models (e.g., using large datasets)"
- "Reassess criteria for determining carbon neutrality… move away from saying 'carbon stocks are increasing/stable' and stating biomass is carbon neutral"

Drax (2019) confirmed plans to install bioenergy with carbon capture and storage (BECCS) technology on two of its biomass units by 2030, with the ambition of becoming carbon negative. Power BECCS also plays a prominent role in the UK's Net Zero Strategy (outlined in Box 2), with the assumption it can deliver negative emissions to offset residual emissions from hard-to-decarbonise sectors. It is therefore crucial to understand the carbon impact of this intervention compared to a scenario in which it is absent.

Methodology

Buchholz et al. (2021) undertook a consequential life cycle assessment (cLCA) for bioenergy feedstocks derived from three Drax-owned pellet mills in the Southern US (Figure 1) and consumed at electricity facilities in the UK, compared to a plausible forest management and electricity grid scenario without bioenergy demand. This updated methodology uses the same data for forest harvest and the wood pellet supply chain, this time with CCS added to the bioenergy power plant from 2030. The methodology for both original and supplementary analysis is summarised in Box 1.

This analysis demonstrates the importance of addressing the full value chain of carbon stocks and flows of an intervention, compared with a 'baseline' counterfactual scenario, if the intervention were absent.

This is a model based outcome with all typical data and model uncertainties associated with such a scientific study. Using verifiable inventory data and established and well vetted ecological models is key to keeping uncertainties at a minimum.

This approach is consistent with the GHG Protocol's pilot Land Sector and Removals Guidance (2022), which states, on evaluating the impact of major business decisions, that actors should consider "avoided removals (removals that would have otherwise happened, but that, as a result of a company's activities, did not happen)," and use "intervention accounting methods… [to] assess the GHG impacts of an action compared to the conditions most likely to occur in the absence of the action. Companies should use the results to ensure that actions lead to global net GHG benefits."[1]

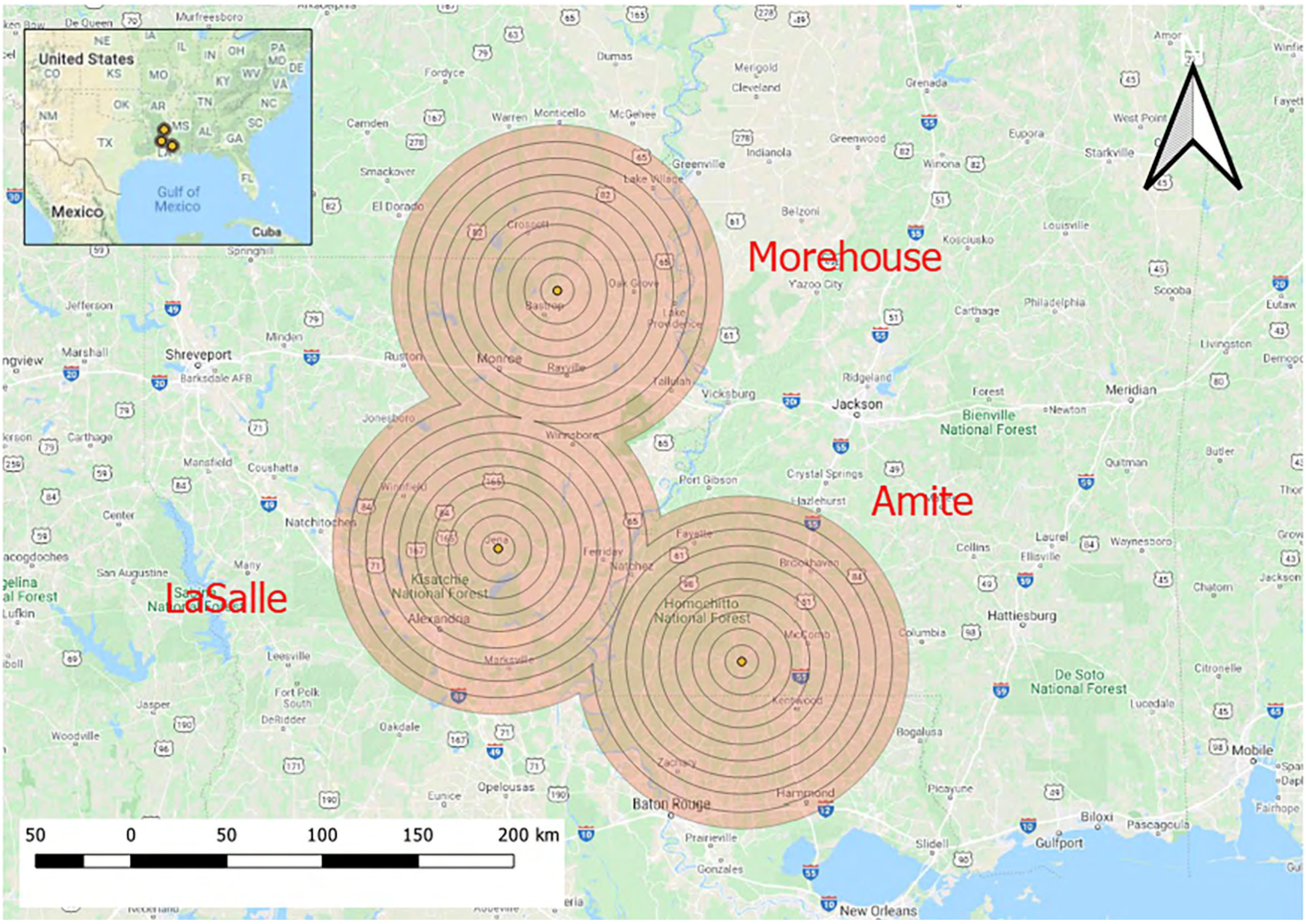

Figure 1. Drax pellet plant locations in Louisiana and Mississippi with an 80 km supply radius. Through a subsidiary known as Drax Biomass, one of the UK's largest electric stations, Drax Power, owns and operates three pellet mills across Mississippi and Louisiana. The plants have an annual nameplate capacity of 450,000 (LaSalle) to 524,000 (Amite, Morehouse) Mg of wood pellets (Drax Biomass International, 2020). Figure replicated from Buchholz et al. (2021).

[1] Pilot guidance is subject to change before finalisation.

Box 1 – Methodology summary

More detail can be found in Buchholz et al. (2021).

Original methodology

- Unlike attributional LCAs, Buchholz et al. (2021) conducted a consequential LCA on the wood pellets harvested in the three Drax pellet mills. According to Ekvall (2020), "an attributional life cycle assessment estimates what share of the global environmental burdens belongs to a product. A consequential LCA gives an estimate of how the global environmental burdens are affected by the production and use of the product."
- Buchholz et al. (2021) explain "in the case of the Drax pellet mills, this requires integrating the anticipated change of carbon stocks in the forest under a bioenergy demand scenario compared to a baseline scenario without demand. Only when the combined effects of both avoided electricity-generation GHG emissions and landscape carbon fluxes including processing GHG emissions are accounted for, can a GHG emission parity point be established."
- The Buchholz et al. (2021) analysis therefore comprised carbon stocks and flows (i) in the forest, (ii) during product processing and transport for all products and post-use for both short-lived and durable wood products, and (iii) avoided electricity generation emissions from fossil fuels for electricity generation in the UK.
- Regional experts were consulted to verify plausible 'baseline' and plausible 'bioenergy' scenarios to form the forest carbon stock basis. The baseline scenario assumed that the 2.8 million ha of non-industrial private forest surrounding the pellet mills would continue to be actively managed, with clearcuts at 25 years in both scenarios. Additional thinning was modelled to occur at year 15 in the 'bioenergy' scenario.
- Growth and harvest simulations were run using the US Department for Agriculture Forest Service's Forest Vegetation Simulator (Southern Variant) (FVS-SN; USFS, 2020).
- The 2018 UK grid mix and a 2025 UK grid emission profile for electricity generation were used to substitute for bioenergy in the baseline scenario. This factor includes a proportion of fossil fuel powered generation and is likely favourable to the bioenergy scenario as the actual grid factor is likely to continue on a downward emissions trajectory from 2025 to 2030 and beyond.

Supplementary methodology

- In the update presented below, the bioenergy scenario now includes an assumption that BECCS will become fully operational on all four units at Drax Power Station in 2030. This assumption is more optimistic than Drax's current plans to convert only two out of four of their biomass units to BECCS. The analysis models a 90% capture and storage of the CO_2e from the power station flue gas (e.g. Brand et al., 2021).
- It is also assumed that 27.5% of the electricity output of the plant is used to power the carbon capture technology itself (based on evidence provided by Drax Group PLC (2021) to the UK Parliament). Two potential options have been analysed:
    a. The biomass power plant compensates for this shortfall (known as the energy penalty) by increasing its sourcing of wood pellets in order to maintain a consistent amount of electricity output. The same forest carbon trends continue post CCS implementation, but the supply area is enlarged. The acreage in the enlarged forest area is identical in stand conditions to the original.
    b. The net electricity produced by the biomass power plant drops by 27.5% and is compensated by other sources of generation in the UK, based on a fixed 2025 projected UK grid conversion factor (GHG per unit of electricity generated).
- The resulting analysis therefore shows how the CO_2e balance over time differs between scenarios in which the UK BECCS plant does and does not exist.

Results

The analysis found that reaching emissions parity between the two scenarios (i.e. the time when atmospheric carbon stocks in each scenario would equalise) would take until approximately 2053 (Figures 2 and 3). Therefore, the BECCS scenario would only produce additional 'negative emissions' compared to the counterfactual from approximately 2053 onwards, decades later than assumed by current plans.

Even with CCS technology fully operational from 2030 at the UK power station, the 'bioenergy/BECCS' scenario demonstrates a less favourable climate impact than were the UK BECCS plant not to exist at all. This is because thinning forests to meet wood pellet demand for UK BECCS results in a reduced capacity for the forests to remove carbon from the atmosphere compared to the counterfactual without BECCS demand, until approximately 2053. Although 90% of the emissions from wood pellet combustion are captured at the power station from 2030, this is outweighed by the impact of more intensive forest management on forest carbon sequestration capacity.

While both scenarios do show a long-term trend to increase forest carbon stocks over time, the BECCS scenario continues to maintain lower forest carbon stocks than the counterfactual scenario due to the higher thinning rate for approximately 20 years, whether wood pellet inputs are increased or substitute electricity generation in the UK is included to offset the BECCS energy penalty.

While individual trees typically show an increased growth rate following a thinning, net primary productivity and therefore carbon sequestration for the entire stand decreases – at least for several decades (Buchholz et al., 2021, p. 7).

Figure 2 compares the atmospheric carbon stock over time in both the 'BECCS' and 'counterfactual (no-bioenergy or BECCS)' scenarios. It demonstrates that the 'BECCS' scenario generates higher net emissions than the 'counterfactual (no-bioenergy or BECCS)' scenario until 2053.

Figure 3 shows the difference between the 'BECCS' and 'counterfactual (no-bioenergy or BECCS)' scenarios, with the 'counterfactual (no-bioenergy or BECCS)' scenario zeroed for ease of comparison. The implications of this gap for UK Net Zero commitments are outlined in Box 2.

To check for robustness, the analysis also reviewed a pathway (option b in the methodology, Box 1) in which the energy penalty accrued in the BECCS scenario was compensated by alternative grid generation, rather than by increasing wood pellet supply.

Similarly, this scenario does not reach parity until 2052.

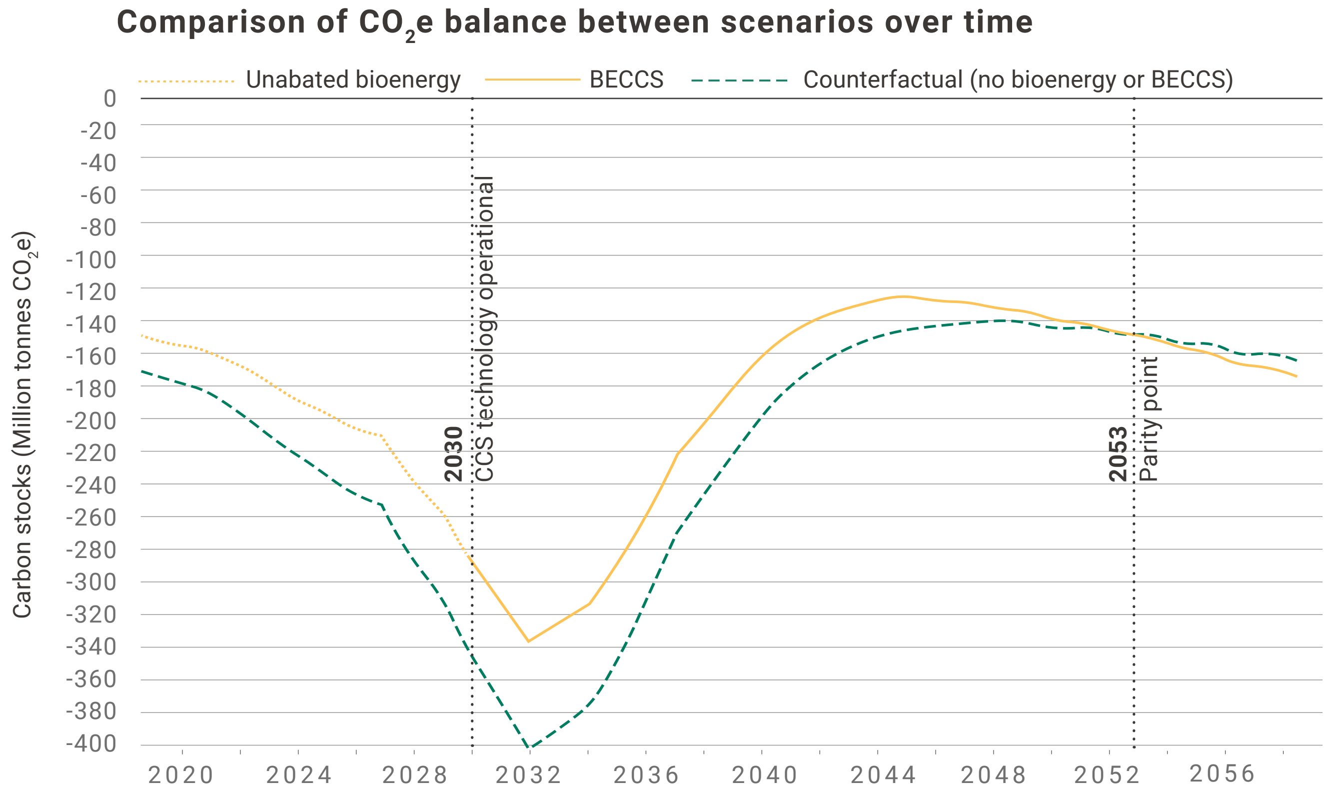

Figure 2

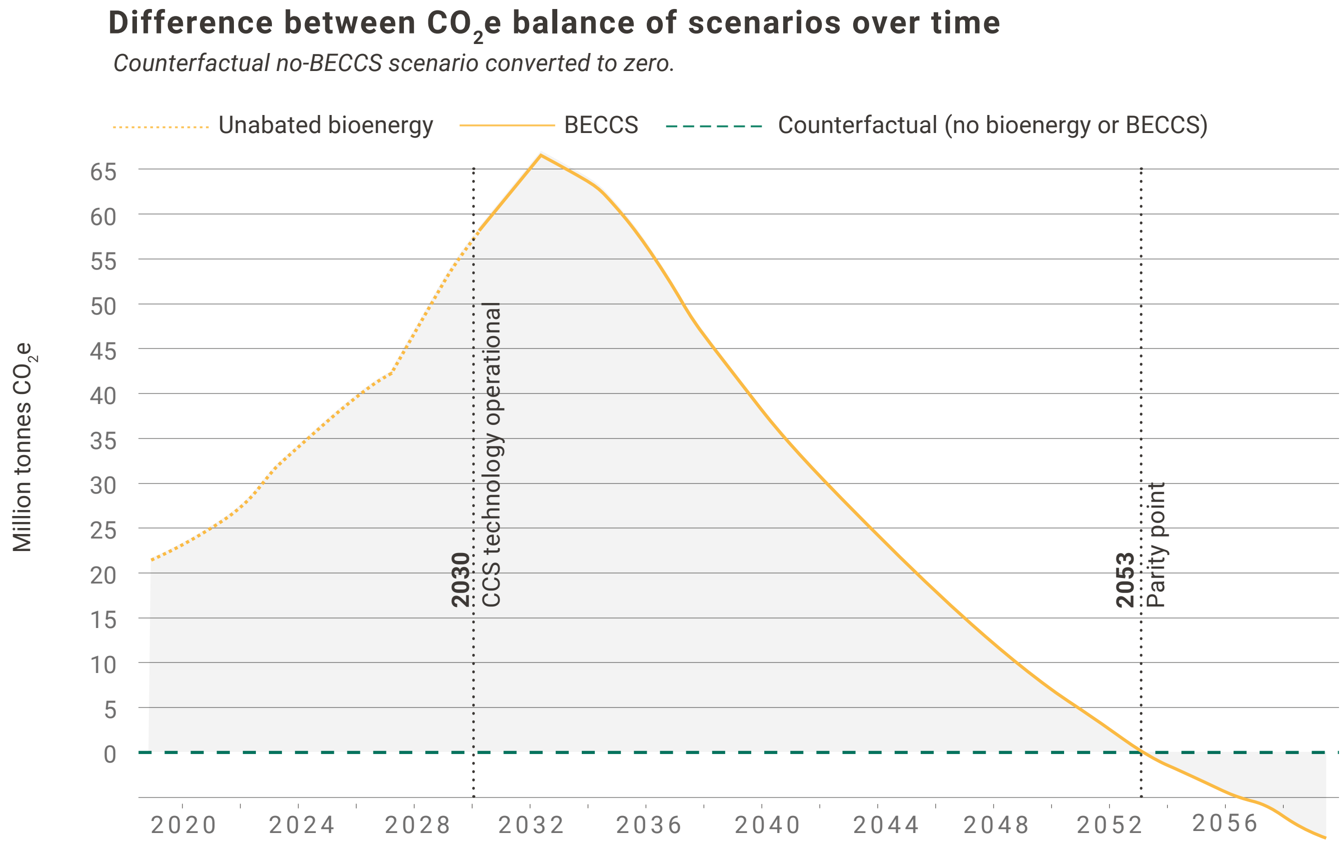

Figure 3

Box 2 – UK policy and carbon budget implications

- The UK's plan to meet its legally binding Net Zero targets, Net Zero Strategy: Build Back Greener states "By 2030 we envisage significant deployment of mature BECCS technologies" (DESNZ and BEIS, 2021). The first power BECCS projects will be eligible for a Final Investment Decision as part of the government's CCUS Cluster Sequencing programme from 2027 (DESNZ, 2023).
- Government plans include all types of Greenhouse Gas Removal (GGR) technologies delivering 6 $MtCO_2e$ of removals by 2030, and 23 $MtCO_2e$ by 2035. By 2050, the Net Zero target includes deployment of engineered removals at a large scale, between 75 and 81 $MtCO_2e$ per year, with BECCS as the dominant technology.
- The next legally binding carbon budget after BECCS is planned to be deployed at Drax in 2030 is Carbon Budget 6 (2033-2037).
- Current emissions plans in the UK's Carbon Budget Delivery Plan only provide 32 $MtCO_2e$ leeway against Carbon Budget 6 (HM Government, 2023).
- During the Carbon Budget 6 period (2033-37), the atmosphere sees a peak of 66$MtCO_2e$ additional emissions from the projected BECCS system (in 2033). In 2037, the end of the Carbon Budget 6 period, the additional atmospheric CO_2e from the projected BECCS system is approximately 42$MtCO_2e$. This impact is currently ignored in UK carbon accounts, where the BECCS system is assumed to provide genuine negative emissions, in the region of 20$MtCO_2$ during the Carbon Budget 6 period.
- The Net Zero Strategy states "Accounting for emissions associated with international supply chains presents a challenge for GGR carbon accounting, and we will engage with our international counterparts to ensure best practice is achieved" (page 195).
- Given the sensitive margins in carbon budget planning, the UK government should undertake and adopt a full value chain cLCA approach to test each policy intervention before implementation. This should rule out interventions which increase atmospheric CO_2e compared to the counterfactual.

Conclusion and recommendations

- Updated cLCA analysis suggests that a UK BECCS system based on wood pellet supply from Drax pellet mills in the Southern US would increase, rather than decrease, levels of atmospheric CO_2e compared to a scenario without BECCS demand, until approximately 2053.
- In 2037, the end of the UK's Sixth Carbon Budget period (2033-37), the additional atmospheric CO_2e from the projected BECCS system is 42 $MtCO_2e$. This is counter to what is expected in the UK's carbon budget plans, which expect that BECCS will provide around 20$MtCO_2e$ carbon removals by 2035.
- Given the urgency to meet near-term emissions budgets to avert climate tipping points, underlined by the Paris Agreement, it is essential that investors and policymakers consider the near-term carbon impact of their interventions relative to counterfactuals. In this analysis, UK BECCS from existing wood pellet supply regions does not provide short-to medium-term climate benefits, despite its prominence in Net Zero plans.
- This analysis underlines the importance of assessing counterfactuals for climate policy choices. It is only when comparing the BECCS scenario to a counterfactual pathway without BECCS that the relative impact on the overall carbon balance is apparent.
- Governments and institutions should undertake and adopt a full value chain cLCA approach in order to accurately make a full carbon account of interventions which aim to reduce atmospheric carbon.
- All stakeholders should continue to monitor the investment implications of evolving sustainability standards and GHG accounting and disclosure, for example via the GHG Protocol, as updates may reveal that currently prominent technologies or supply chains are higher carbon than previously believed.

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