
# Beyond BECCS:

## The Case for a Reduced Reliance on Bioenergy Carbon Capture and Storage in Meeting Net Zero

**This report, written jointly by the RSPB and WWF UK, summarises research conducted to examine whether it is possible to reduce the UK's future reliance on BECCS and still achieve net zero emissions by 2050, whilst understanding the wider environmental and land use implications of these decisions. It makes the case for a more precautionary approach to BECCS than currently planned by the UK Government and outlines how this could be achieved.**

# Executive Summary

## Context

The climate emergency has fast become the greatest threat to biodiversity globally. Crucially, both are interlinked and tackling both the climate crisis and biodiversity crisis are mutually supporting goals.[1] At 2°C of warming, one in ten of all species would find themselves at a high risk of extinction.[2] Yet, at the same time, a critical ally in tackling the climate emergency is nature itself, and we will rely upon it to adapt to a rapidly changing climate as well as to store and sequester carbon.[3] It is therefore vital that the UK is successful in at least meeting its legally-binding net zero emissions target by 2050, and ideally achieving RSPB and WWF-UK's more ambitious net zero target of 2045. Given that the UK is one of the most nature-depleted countries in the world, with one in six species threatened with extinction, our efforts to reach net zero must not compromise biodiversity, and where possible work to restore it.[4]

In achieving net zero, it is likely to be impossible to reduce all sources of greenhouse gas (GHG) emissions to zero. Some will need to be offset (mopped up) by greenhouse gas removal from the atmosphere, which may also be required to remove historic carbon dioxide ($CO_2$) too. As one option for doing so the UK Government is increasingly looking to develop Bioenergy with Carbon Capture and Storage (BECCS). This is when biomass (energy crops, waste, and wood) is burned to generate electricity, used to create hydrogen or to fuel heavy industry with the $CO_2$ captured and stored. According to international accounting rules, biomass is counted as zero carbon at the point of combustion (even if burning it releases all the carbon that had been captured from the atmosphere into the plants) so it would, on paper, create negative emissions if the resulting $CO_2$ emissions were captured and stored. It is assumed BECCS can therefore offset ongoing pollution from other sectors such as aviation, farming or heavy industry.

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# Challenges with BECCS

Although BECCS may be a necessary part of achieving net zero in the UK, a heavy reliance is highly problematic for six key reasons:

1. **It is a suite of technologies that don't yet exist together at a commercial scale, and therefore relying on it to achieve net zero is a gamble.** In particular, carbon capture and storage (CCS) is not operational in the UK and existing international examples demonstrate the unforeseen complications that can arise when storing $CO_2$ underground.

2. **It may not always deliver the expected levels of negative emissions,** particularly if relying on burning wood from forests, due to:
    a. Long carbon payback periods ranging from a few years to centuries.[i]
    b. Foregone sequestration which is the sequestration that would have occurred if the biomass was not harvested.
    c. Outdated international accounting rules which mean the UK does not have to count the climate impact of harvesting forest biomass from other countries, despite the fact that many of the countries it imports from don't have robust methods for measuring this for themselves.

3. **There is evidence that biomass harvests to fuel bioenergy in the UK are harming forest ecosystems and nature.**

4. **It requires huge land use either to cut down trees from forests or to grow energy crops** which may compete with nature and food production either in the UK or overseas. The land area required is many orders of magnitude greater than the land needed for producing the same energy from wind and solar; and in the UK land is scarce and also in demand for nature, food and wood.

5. **It can delay or deter real action to reduce emissions.**

6. **BECCS will cost vast sums of money to fund,** both to operationalise and to subsidise the electricity and negative emissions generated. These costs will be passed onto UK households.

i The carbon payback period is the length of time it takes before the $CO_2$ released during the burning of biomass is captured when plants or trees are planted and re-grow.

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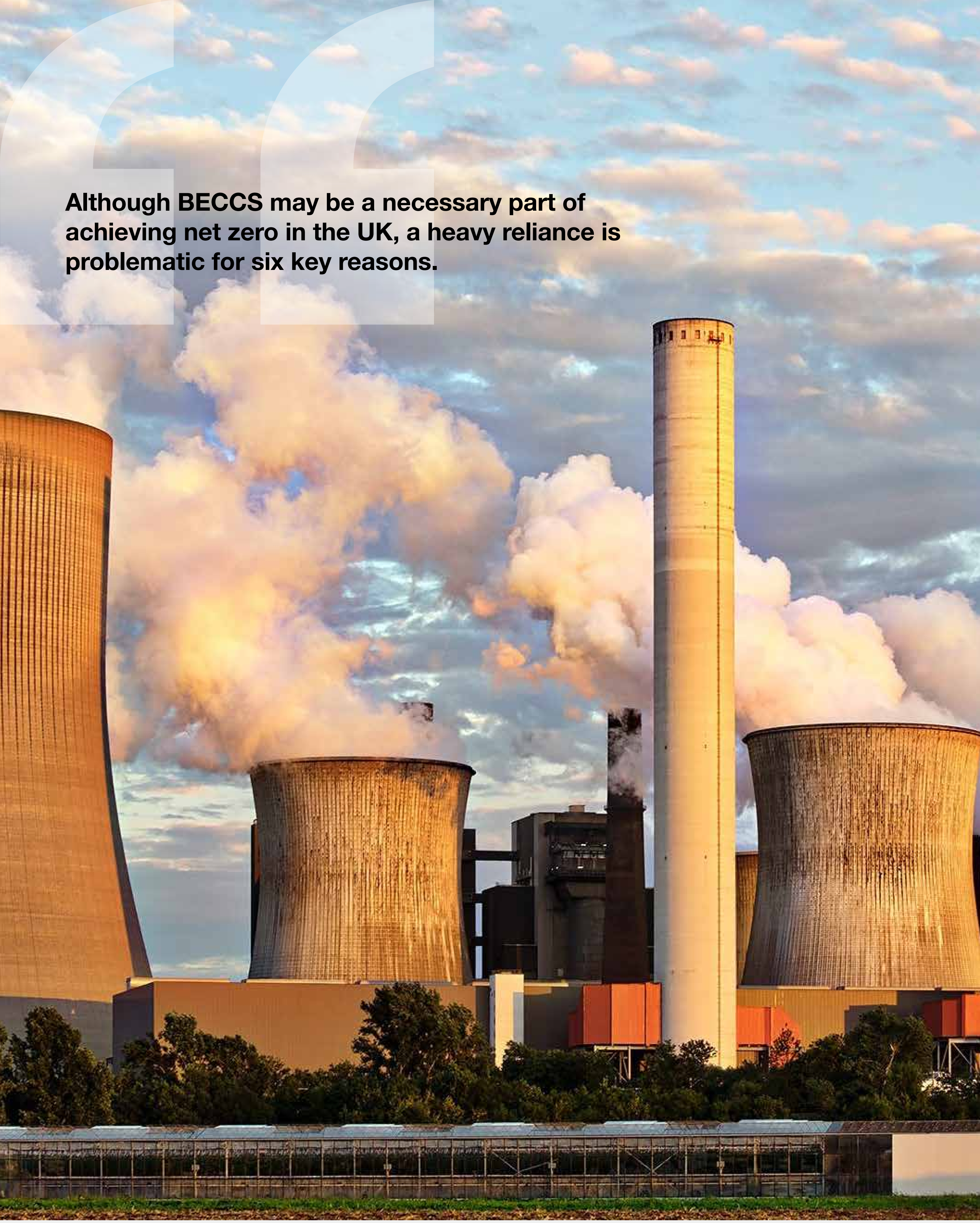

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# The Research

In light of the risks posed by a large reliance on BECCS to reach net zero, WWF-UK and RSPB commissioned new research from University College London, Exeter University and the University of Southampton to explore whether it is possible to reach net zero with a reduced reliance on BECCS.

Four scenarios were modelled, each one modelling both the UK energy system and resulting changes in land use cross Great Britain:

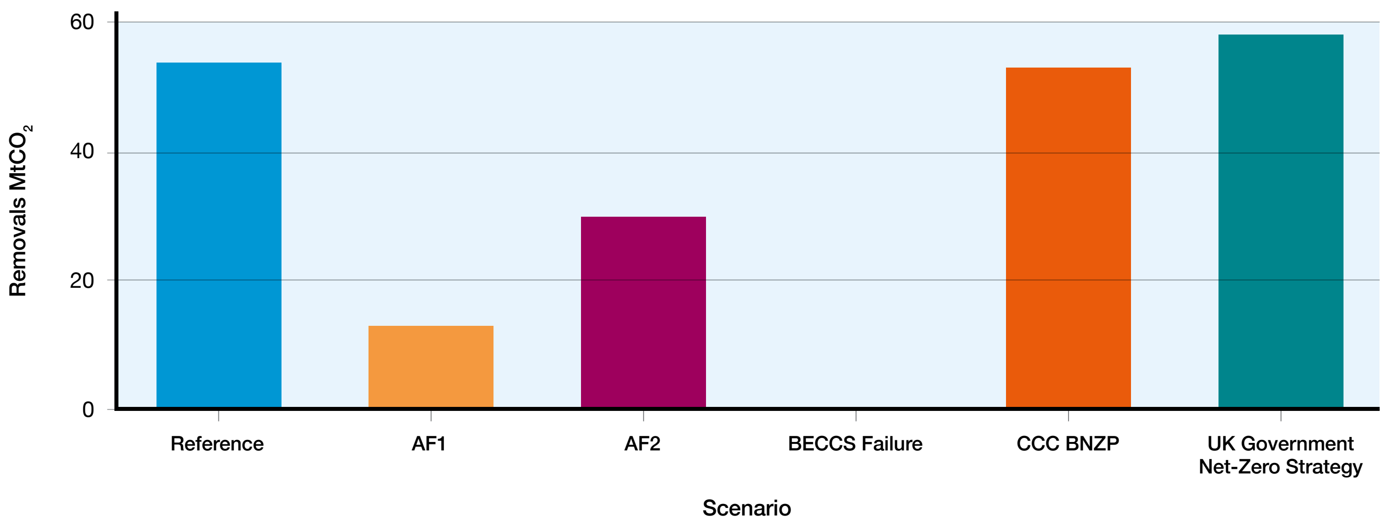
- The Reference scenario is similar to the Climate Change Committee's Balanced Net Zero Pathway (CCC BNZP).
- Alternative Future 1 (AF1) meets net zero with a low reliance on BECCS removals, which is enabled through significant behavioural shifts across society alongside ambitious end-sector electrification and afforestation.
- Alternative Future 2 (AF2) meets net zero with a moderate reliance on BECCS, but relies more heavily on other technology like Direct Air Carbon Capture and Storage (DACCS).
- BECCS Failure is a scenario which closely matches the Reference scenario, with limited behavioural shifts seen across society, but where CCS technology fails to materialise. BECCS therefore fails to deliver at scale and the UK misses its climate targets.

Neither organisation advocates for any one of the scenarios presented in this work, which instead seeks to present the trade-offs that are associated with different options.

# Summary of Key Results

The UK can reach net zero and keep the power on with a significantly reduced reliance on BECCS: Two scenarios significantly reduce the UK's reliance on BECCS to get to net zero, whilst also eliminating unabated biomass generation from 2030.

**Figure 1: Annual removals from power-BECCS and hydrogen-BECCS in 2050 across modelled scenarios. Across the scenarios there are low levels of biomass, primarily municipal solid waste, coupled with CCS used in industry for cement, however the levels are negligible.**



**This will require significant additional decarbonisation action across the economy:** In particular, the UK will need to ramp up end-sector electrification and nature restoration in addition to reducing energy consumption and improving energy efficiency, shifting to more sustainable diets and reducing aviation demand.

**The UK could miss net zero and significantly increase costs if it relies on BECCS and it fails:** If the UK relies heavily on BECCS but it fails to materialise as a scalable technology, the UK could miss net zero. If on the other hand, the UK takes additional steps to decarbonise, net zero could still be reached even if BECCS deployment is intentionally later and lower.

**There are a multitude of benefits to reducing our reliance on BECCS:** In particular, less demand for biomass frees up land for nature restoration and food and wood production. The quantities of BECCS proposed by the UK Government would require enormous areas of land either domestically or overseas to grow the feedstock, which would directly compete with food production, particularly on arable land. On the other hand, land use requirements for renewables such as wind and solar are relatively small when generating the same amounts of electricity.

Decisions about bioenergy result in trade-offs in land use. Reducing our reliance on BECCS requires greater investment in nature-based solutions such as tree cover expansion, peatland restoration and saltmarch re-creation, as well as faster reductions in emissions across the economy. If done in the right location these nature-based solutions can improve biodiversity, but may still lead to reductions in food production, particularly if highly productive land is displaced. This trade-off could be reduced by careful spatial prioritisation through a land-use framework, rewarding farmers for restoring nature in the right locations alongside ongoing food production, improving crop yields and prioritising crops for human food production over livestock feed production.

# Recommendations from the Research

Based on the insights gained from our modelling, we recommend that the Government takes four key steps to reduce our reliance on BECCS and instead focuses on restoring nature across the UK:

1) Take a precautionary approach to BECCS with strict limits on its rollout that constrain it to the levels of genuinely sustainable feedstocks available and strengthen the BECCS regulatory framework. The UK Government should rule out eligibility for energy subsidies of any wood from forests.

2) Eliminate unabated biomass generation by ending subsidies before 2027.

3) Invest more in nature and reward farmers and foresters for protecting nature and storing carbon.

4) Go much further and faster on decarbonising the whole economy and reducing energy demand.

# Context

## What is Bioenergy and BECCS?

Bioenergy uses fuel from biological origins (wood, crops, wastes) to generate power or heat, to create liquid biofuels used in transport, or to create hydrogen. There are now increasing efforts to develop BECCS as a 'negative emissions technology' (NET), to remove $CO_2$ from the atmosphere and store it underground.

Today, the UK uses biomass for energy in its transport, heating and electricity sectors, with bioenergy providing about 13% of the UK's electricity in 2021 and 5% of the UK's road transport fuel.[5] The UK imported roughly 9.1 million tonnes of wood pellets in 2022 for electricity generation, making it the largest net importer of forest products in the world.[6] Roughly 80% of these pellets come from North America, with the remainder from Europe, principally the Baltics.

The 'zero carbon' rating for biomass energy under the EU and now UK Emissions Trading Schemes, and in broader UK energy policy, has enabled it to receive £1bn in carbon tax breaks since 2012. Between 2012 and 2027 energy bill payers will spend £13 billion in direct support to large biomass power plants.[7] This has led to significant criticism from some scientists who warn that burning wood in power stations increases emissions for decades or centuries.[8] Scientific advisors to the UK's largest biomass power plant advised that it should move away from stating that biomass is carbon neutral as a blanket term.[9] It has been estimated that if the total lifecycle emissions from burning wood were counted, UK greenhouse gas (GHG) emissions from UK electricity generation would have been 22-27% larger in 2019.[10]

## Why is BECCS Part of the Net Zero Conversation?

BECCS and other NETs, such as Direct Air Carbon Capture and Storage (DACCS),[ii] have risen in prominence in climate models over the past two decades. From a seedling of an idea at the turn of the millennium, BECCS has become a fundamental component of nearly all modelled pathways that keep the world within 1.5°C of warming.

NETs play a significant role in offsetting (or mopping up) emissions that remain from other sectors, as well as to re-absorb $CO_2$ released into the atmosphere in the past. BECCS can, in theory, simultaneously do two things: reduce $CO_2$ concentrations in the atmosphere and generate energy (in the form of heat, electricity, hydrogen, or liquid fuels). The three main end-uses for BECCS commonly used in climate pathways that reach net zero are in generating electricity, in industrial processes through combined heat and power,[iii] and in processes that produce low or zero carbon road fuels.

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ii Direct Air Carbon Capture and Sequestration: How It Works and How It Could Contribute to Climate-Change Mitigation - ScienceDirect.

iii A process that captures and utilises the heat that is a by-product of the electricity generation process.

There are a multitude of benefits to reducing our reliance on BECCS. In particular, measures like dietary shifts and reductions in demand for energy can help to free up land for nature.

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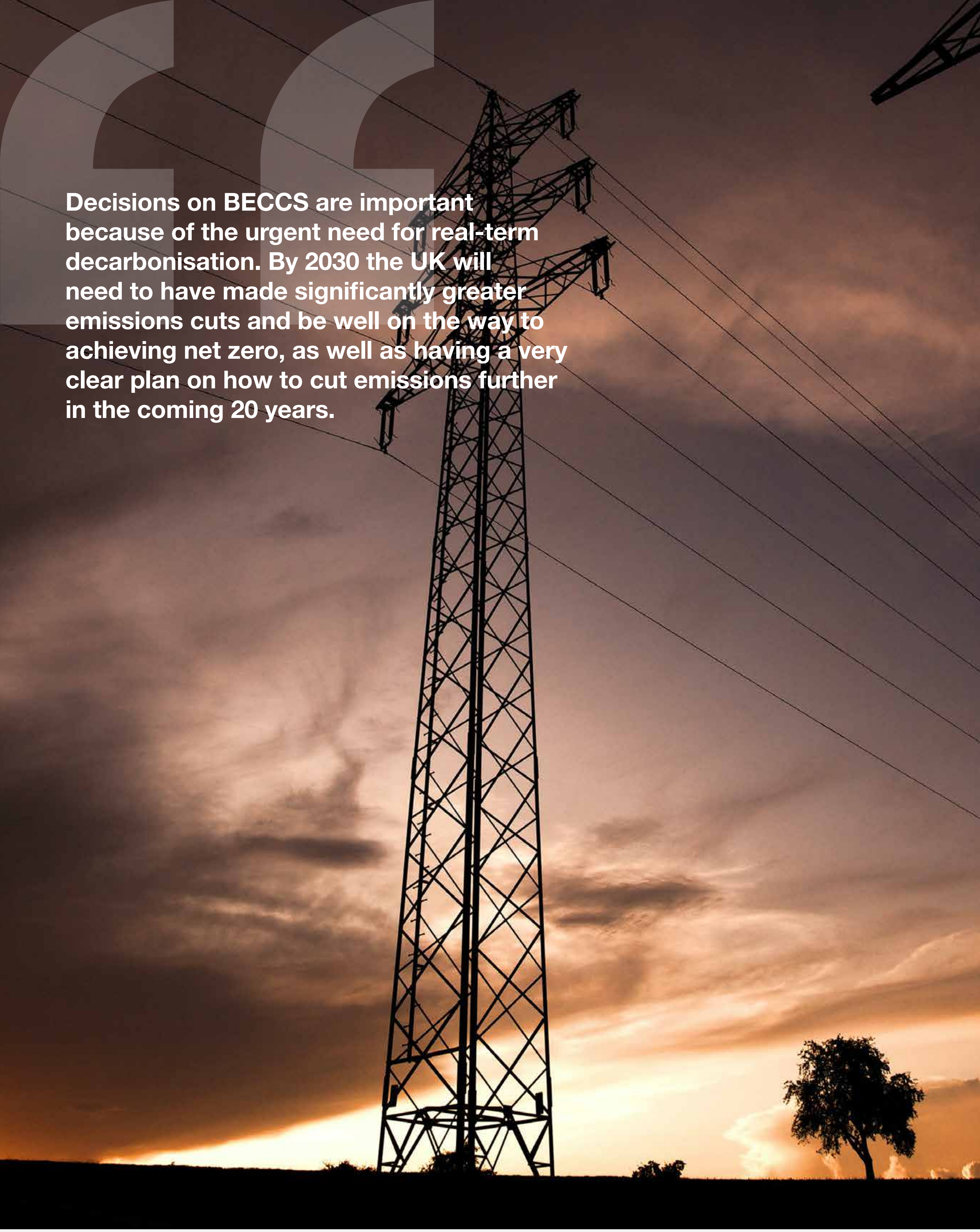
**Decisions on BECCS are important because of the urgent need for real-term decarbonisation. By 2030 the UK will need to have made significantly greater emissions cuts and be well on the way to achieving net zero, as well as having a very clear plan on how to cut emissions further in the coming 20 years.**



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The prominent role of BECCS is derived from a set of assumptions within emissions models, notably:

- That certain sectors of the economy, like aviation and agriculture, will only decarbonise moderately (due to limited ambition of demand-side options), meaning vast volumes of BECCS, or other NETs, are required to mop up the residual emissions. [11]
- That BECCS can be scaled globally in time to avert the most dangerous climate scenarios, despite evidence to suggest that feasibility and availability of the technology is uncertain. [12, 13, 14]
- That the use of high social discount rates, which convert the future benefits and costs of public policy into their value today, mean that models opt for delayed mitigation strategies. Higher discount rates place a higher value on the costs and benefits of policies now, with future impacts and benefits given less importance. This means that in the models it is cheaper to avoid taking action now to decarbonise and pay more for carbon removal technologies into the future. Models with lower discount rates rely less on BECCS. [15]

## Why is this Important Now?

Decisions on BECCS are important because of the urgent need for real-term decarbonisation. By 2030 the UK will need to have made significantly greater emissions cuts than thus far and be well on the way to achieving net zero, as well as having a very clear plan on how to reach net zero by 2050. If the UK Government gambles on BECCS to achieve net zero in 2050, but the technology does not materialise, it might fundamentally undermine our chances of reaching net zero.

The latest IPCC climate report shows a series of abrupt shifts between atmospheric warming of 1.5°C and 2°C, where drastic climate tipping points could be triggered that generate cascading impacts that cannot be undone by removing $CO_2$ from the atmosphere. [16] Projections suggest these could be reached far sooner than anticipated, even within this decade. [17, 18] At the global level, BECCS and other NETs are often used as a justification for letting temperature rises exceed 1.5°C (often called 'overshoot'), based on the claim that this carbon can be reabsorbed later. However, BECCS (and other NETs) are only likely to be deployed at scale post-2030, and by then some irreversible impacts on global warming may have been triggered. The priority right now must be to immediately and drastically reduce greenhouse gas emissions. Where the UK leads, many other countries follow, especially when it comes to climate change; the UK's approach to BECCS may well inform the choices of others.

## Negative Emissions Technologies in the UK

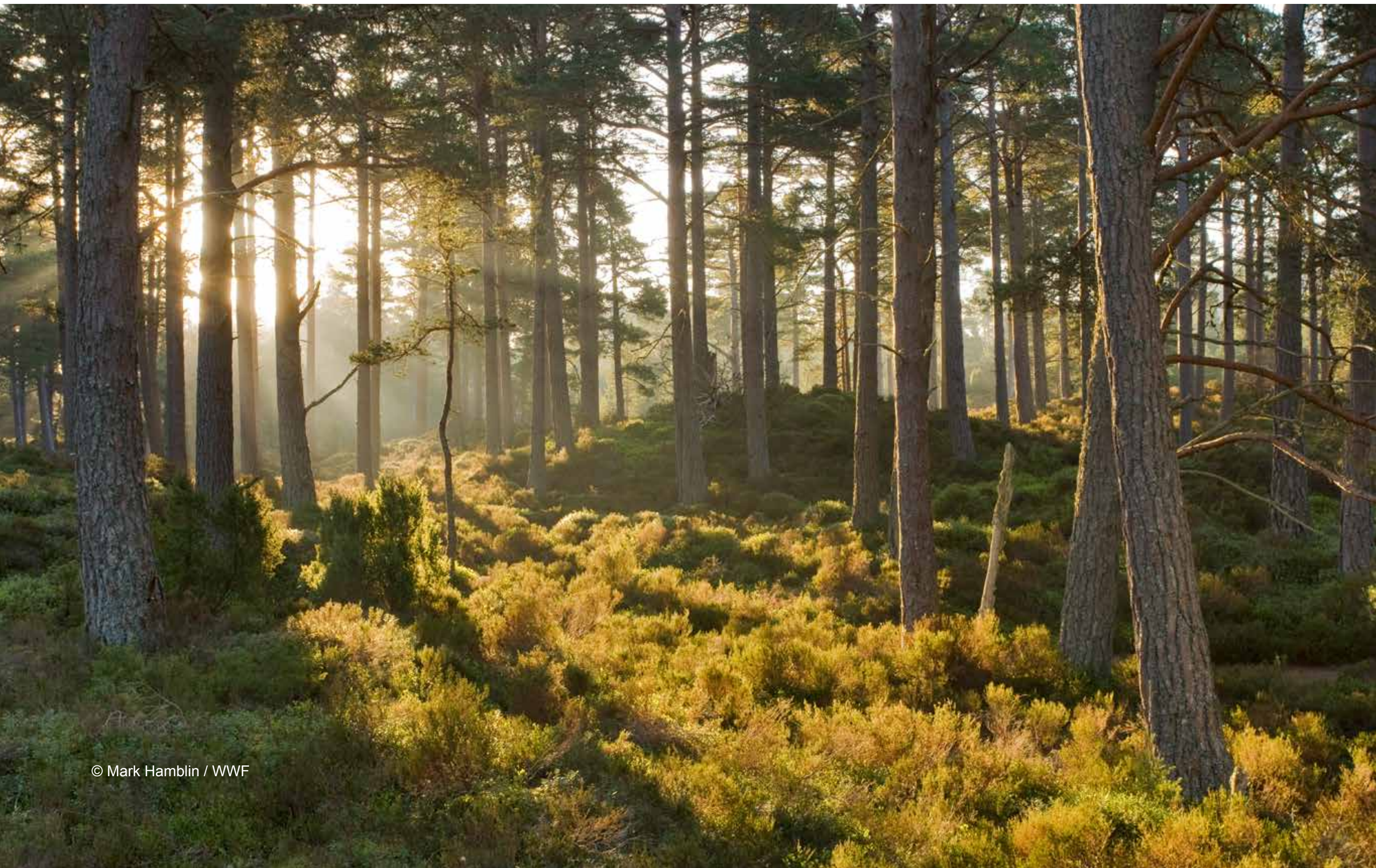
NETs are relied upon to varying degrees across the four UK Governments' net zero plans. The independent Climate Change Committee (CCC) advises roughly 53 $MtCO_2$ of BECCS per year to achieve net zero emissions across the UK by 2050, while the UK Government's Net Zero Strategy envisages around 53-58 $MtCO_2$ of BECCS removals by 2050. [19] The CCC's scenario would require around 0.7 million hectares of land to grow sufficient bioenergy crops, or about 4% of the UK's total agricultural land area (in addition to a high reliance on imports). Replacing even some imported wood with home-grown energy crops poses trade-offs for UK land use and efforts to increase energy crops grown in the UK have stalled for many years.

Currently, large-scale biomass generators, like Drax power station, receive renewable energy subsidies (Renewable Obligation Certificates) for burning biomass without carbon capture. These are expected to come to £3.7bn between 2020 and 2027.[20]

Bioenergy has not proven cheap so far - it is by far the most expensive energy technology receiving subsidies. Whilst wind and solar are so cheap that they can help bring down energy bills (if coupled with electricity market reform), bioenergy adds to household energy bills. Bioenergy is also forecast, by the Government, to become even more expensive.[21]

The Government published its Biomass Strategy in August 2023. It states that BECCS is the best use of biomass resources in the medium to long-term and confirms that it will play a large part in reaching net zero. In 2022, the Government consulted on business models for funding BECCS power plants in the future. Their preferred position is for a combined Contract for Difference subsidy, using money drawn from energy bill payers, that would pay for both the generation of electricity and for sequestered carbon. Such a business model was proposed by Drax for longer-term BECCS subsidies in 2021.[22] The Climate Change Committee and the Government also see BECCS playing other roles beyond generating electricity, such as helping to decarbonise industry or generating hydrogen.

The ability of the devolved nations to influence future UK energy policy is limited in general, and market support for different forms of power generation are reserved to the UK Government. However, important policy levers including environmental regulation, planning permission and agricultural policy remain devolved. BECCS may be important across the devolved nations; the CCC have advised that Northern Ireland could remove 1.1 $MtCO_2$ by 2050 through BECCS, and they do not assume the deployment of BECCS in Wales, while Scotland will be publishing its own Bioenergy Policy Statement late in 2023 which will outline the likely role of BECCS in Scotland. It is unclear how the UK Government's ambition will translate to biomass supply across the UK.



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## Why is Relying on BECCS Risky?

Given the extent to which BECCS is relied on in global modelled pathways that keep the world within 1.5°C of warming, and increasingly in national plans to reach net zero, the question of whether or not BECCS can successfully scale, deliver negative emissions and remain within ecological planetary boundaries could not be more crucial. For the reasons outlined below, we don't yet know the answer to this question. BECCS, and other NETs, are therefore potentially 'an unjust and high stakes gamble' if they negate strong mitigation in the near term.[23] This is the case even if we will need some BECCS in the future. If we rely on NETs, but they are not deployed or are unsuccessful at removing $CO_2$ from the atmosphere at the levels assumed, society will be locked into a high-temperature pathway.

# 1.

### BECCS may not scale in time or may perform less effectively than anticipated

BECCS, though often referred to as a single technology, is in fact a suite of often complex supply chains. For BECCS to work, these supply chains (many of which do already exist) will need to be merged in time and space, which brings significant and potentially unforeseen challenges.

**Gap between required and actual operational Carbon Capture and Storage (CCS) capacity:** CCS technology, a core part of BECCS, has received three decades of significant financial support. Despite this, the International Energy Agency concludes the technology 'remains woefully below the level required',[24] with research indicating a 98.5% gap between required and actual operational capacity.[25] Given the long lead times for CCS projects it will be some time before growth in early and advanced development translates into operating projects.[26]

**No functioning CCS projects in the UK:** The UK Government has committed over £2bn since 2010 to the development of CCS. To date, this funding has not resulted in any operational CCS facilities.[27] The UK Government has recently announced a £20bn package for CCS over 20 years.[28] However, the UK has no experience with geological carbon storage and the scale of storage for Drax alone would be unprecedented globally.

**CCS projects internationally are not without complications:** A recent report examined two of Norway's long standing offshore CCS projects, Sleipner and Snøhvit, both of which are consistently cited as proof of the technology's viability.[29] It found that although both are among the most-studied geological oil and gas fields globally, their security and stability has been extremely difficult to predict, and both have encountered substantial issues and additional costs throughout their operating lives. For example in Sleipner, 18 months after injection, the storage site demonstrated acute signs of rejecting the $CO_2$. The report 'casts doubt on whether the world has the technical prowess, strength of regulatory oversight, and unwavering multi-decade commitment of capital and resources needed to keep carbon dioxide sequestered below the sea permanently'.

**Lack of UK BECCS demonstrator projects:** Focussing on BECCS, in late 2021, Drax power plant had captured just 27 tonnes of $CO_2$ in its demonstration plant, but claims it will be able to capture 8 million tonnes by 2030, something that would involve jumping multiple technology development stages rapidly.[30]

**Not all BECCS produces energy or is net negative:** Studies show that some types of BECCS produce low energy efficiencies, which means that the total amount of energy required over the lifecycle of BECCS (e.g. during transport, processing and carbon capture) is not always offset by the energy produced when the biomass is burned.[31] Furthermore, depending on the lifecycle emissions of BECCS across the supply chain, net negative emissions may also not always be achieved (see below).

These challenges present serious complications to the mass deployment of BECCS but this is largely unaccounted for by emissions models.[32] This is not a reason to entirely discount the use of BECCS, instead, given the urgent need for immediate decarbonisation, this uncertainty should add impetus to our action to reduce emissions. Recent research found that uncertainty over carbon dioxide removal lends weight to the argument for decarbonising twice as fast as currently planned in the 2020s.[33, 34]

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# 2.

## BECCS cannot be assumed to be carbon negative

Biomass is often described as carbon neutral because the carbon released when it is burned can, in theory, be removed from the atmosphere by photosynthesis as harvested plants or trees regrow. In practice some types of bioenergy, like wood from forests, release large quantities of $CO_2$ into the atmosphere when burnt and are slow to regrow. This 'carbon payback period' means they may only be carbon neutral after years or decades, if ever.[35] In turn, BECCS using this biomass may not become carbon negative for many years.

Taking total lifecycle emissions from forest biomass into account can lead to an increase in emissions for many years or decades. But these emissions are often not addressed in policy-making or scientific models.[36] These missed sources of emissions include:

1. **Combustion emissions:** When wood is removed from the forest and burned, wood's embodied carbon is released into the atmosphere. However, the wood burned in the UK is always counted as zero carbon under the assumption that forest carbon stock changes will be accounted for in the source country, regardless of whether this happens. This means overall emissions may be underestimated, and as a result the net removals from BECCS overestimated.

2. **Soil carbon loss:** Biomass harvested via the collection of logging residues releases carbon from the soil, which is not calculated in most models looking at international supply chain emissions. This may overestimate BECCS's removal potential (although in UK supply chains soil carbon loss is included in calculations).[37]

3. **Forgone sequestration:** When trees in a forest are replanted, trees are replaced with saplings, which will immediately reduce the amount of carbon the forest is absorbing relative to if those trees had not been cut down. This is known as 'foregone sequestration'. Whether there is foregone sequestration depends on the type of feedstock that is harvested as well as the silvicultural system in place.[38]

Once the uncapturable emissions along the wood pellets supply chain for BECCS are calculated (the emissions that can't be captured at the power station because they occur elsewhere), BECCS isn't always carbon negative, and in some cases may increase $CO_2$ in the atmosphere.[39] Only by fully understanding and accounting for all these emissions can we determine whether a BECCS project contributes to emissions removals.[40]

# 3.

## Biomass harvesting threatens forests

The UK's Biomass Sustainability Criteria came into force in 2014, and have been criticised by some for their inability to ensure that biomass does not harm nature. For example, the impacts of indirect land use change are poorly accounted for. The UK Government's 2023 Biomass Strategy committed to strengthening these criteria, and it is crucial that this eliminates the sustainability breaches within biomass supply chains (see Box 1). However, strengthening these sustainability criteria will never address the fundamental carbon problems surrounding many types of bioenergy (see section above).[41]

Upscaling the UK's reliance on biomass for BECCS could compound sustainability challenges. A report by Chatham House found that scaling BECCS by solely combusting wood pellets to meet the CCC's BECCS 2050 target would require the combustion of more than four times that currently burned at Drax.[42]

## Box 1:
## Bioenergy sustainability breaches

### British Columbia:

Pinnacle Renewable Energy has been found, by NGO Stand.earth and investigations by Conservation North, to source whole trees in order to manufacture its wood pellets. These investigations demonstrated that clearcutting is occurring in British Columbia in areas where felling is licensed to pellet manufacturers.[43] In addition, a BBC Panorama documentary found that a Drax-owned mill had been sourcing wood from primary forests in Canada, despite it claiming to 'avoid damage or disturbance' to primary and old-growth forest.[44]

### North Carolina:

Enviva, one of the largest wood pellet manufacturers in the USA, supplies wood pellets to Drax. NGO investigations, most recently in 2019, have established the use of whole trees by following logging from clearcut sites in North Carolina back to Enviva's pellet manufacturing facilities (including from biodiverse hardwood forests in North Carolina).[45] As recently as 2022 a whistleblower working at Enviva said: *'The company says that we use mostly waste like branches, treetops and debris to make pellets. What a joke. We use 100% whole trees in our pellets. We hardly use any waste. Pellet density is critical. You get that from whole trees, not junk'*.[46]

### Estonia:

A report by Estonian Fund for Nature and Latvian Ornithological Society found 'numerous examples of Valga Puu (a subsidiary of Graanul Invest) clearcutting forests on Natura 2000 sites'.[47] According to data acquired from the Estonian Environmental Board, between 2009-2018, logging licences were issued that covered 82,411 hectares within Natura 2000 sites.


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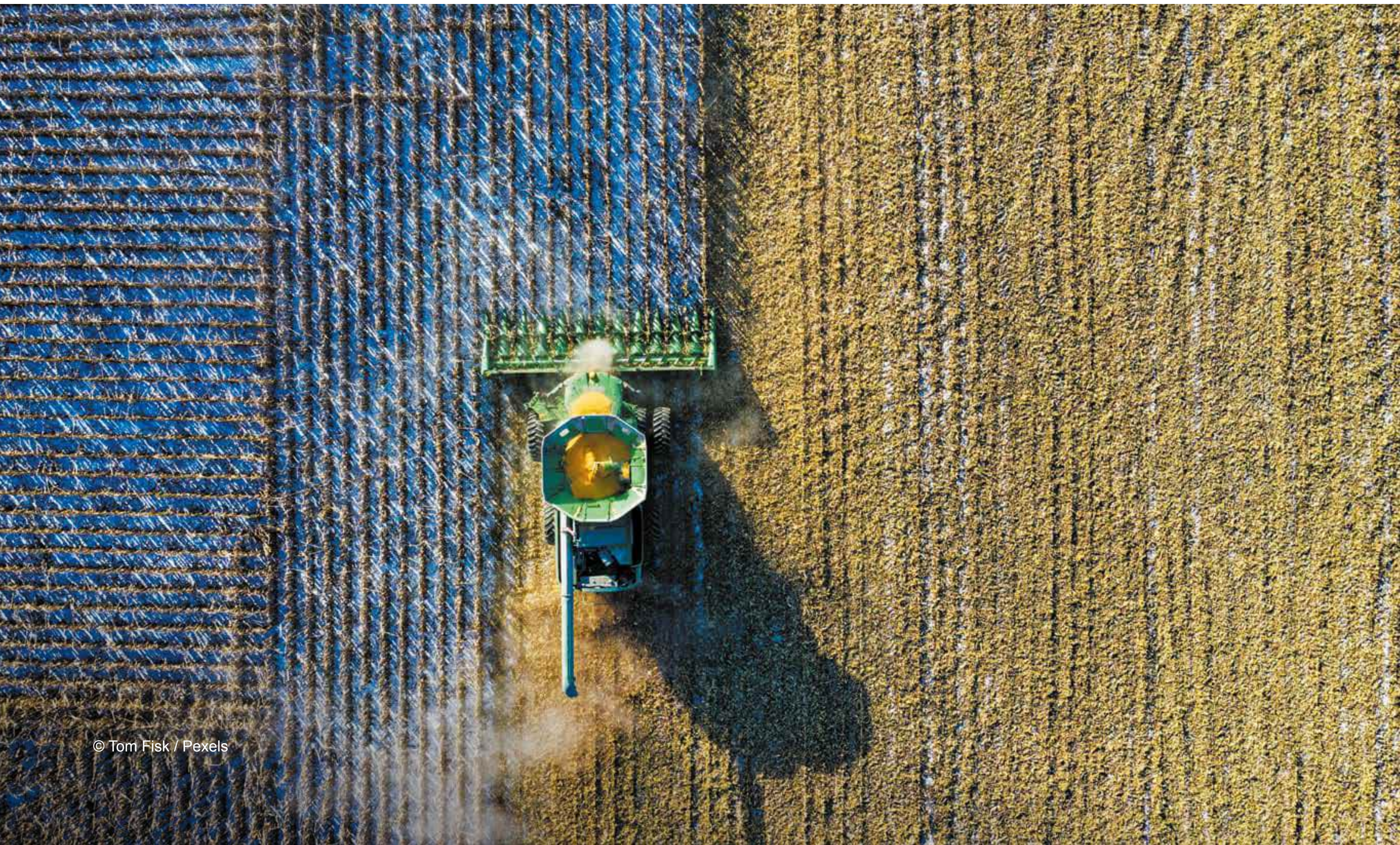
# 4.

## BECCS could have a substantial land and resource footprint, with serious implications for nature and people

In order to generate the level of BECCS that many models rely upon, significant amounts of land and water would be required globally, and in the UK. The IPCC's medium BECCS deployment scenario of 12 $GtCO_2e$ per year could require up to 0.8 billion hectares of land – over twice the size of India – resulting in competition for land with food production or with natural ecosystems.[48] This could require anywhere from 0.7-24.4 billion cubic metres of water per year, across already water-stressed areas (current water used by global agriculture is 8 billion cubic metres). The International Energy Agency's 2023 update to its net zero roadmap envisages about 1GtCO2e of removals by 2050, reflecting concerns about heavy reliance on BECCS at a global scale.[49, vi]

In reality, studies have found that quantities of BECCS between 0.5-5 $GtCO_2e$/year could break sustainable limits and threaten planetary boundaries,[50] although recent research has indicated that our current consumption of biomass globally already transgresses the planetary boundary for biomass.[51] In 2022, the IPCC highlighted that 'BECCS has profound implications for water resources' and 'can significantly impact food prices via demand for land and water', with impacts including 'dispossession and impoverishment of small-holder farmers, food insecurity, food shortages, and social instability'.[52]

In the UK, as noted above, the CCC estimates that anywhere from 0.7-1.4 Mha of domestic bioenergy crops in the UK (around 6% of all the UK's land) by 2050 could be needed to fuel demand for BECCS, alongside ongoing imports.[53]



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## Box 2:
## Should the UK rely on imports of biomass?

Currently, the majority of biomass used for large-scale electricity generation is imported, largely from forests in the USA and Canada. There are no signs that this will change in the near future and industry is investing more in wood pellet production capacity overseas, building and buying wood pellet plants.[54]

Looking ahead, the UK Government's recent Biomass Strategy presented scenarios in which the UK relies heavily on biomass imports for BECCS.[55] In its assessment of future biomass feedstock availability, the Government presented a future scenario with a continued, but smaller, reliance on imported forest biomass by 2050. This scenario also relied heavily on imports of agricultural residues, sawmill residues and, increasingly from 2030, energy crops.

Although the UK may be able to rely on some genuinely sustainable biomass supply from overseas, there are compelling reasons for us to reduce our reliance on biomass imports in the future and it remains the CCC's position that as much bioenergy production should occur within the UK as possible.[56]

**It is difficult to ensure overseas governance results in high levels of sustainability:** The UK Government's Biomass Strategy was clear that the main principle for biomass use is sustainability. However, existing sustainability criteria have been unsuccessful in preventing sustainability breaches within wood pellet supply chains (see Box 1). The forestry industry (which bioenergy is heavily reliant upon) is itself flawed; just last year 100 scientists wrote to the Canadian Prime Minister to warn that Canada's logging practices are incompatible with climate leadership,[57] yet the UK doesn't have control over these practices. This is relevant to social as well as environmental impacts. There have been continued air pollution violations by processing plants in the US that supply wood pellets to the UK power generator Drax which has been forced to make settlement payments for claims against three of its US pellet plants, two of them sited in poor, majority-Black communities.[58]

**The UK's reliance on imports places pressure on land use and biodiversity overseas:** In the UK Government's Biomass Strategy, a scenario was presented in which the UK limits energy crop production to 100-200,000 hectares domestically. This scenario required that the UK imports 245PJ of energy crops by 2050, equating to about 13.6 million dry tonnes and up to one million hectares of land overseas.[59, v]

**Undermining energy security:** Biomass supply is difficult to predict and guarantee into the future. The UK Government's 2023 Biomass Strategy outlined the risks of relying on BECCS in a world where biomass supply is constrained, finding that in this scenario the UK could fail to meet its net zero targets. Given increased extreme weather and climate risks, greater demand for biomass globally (driven in part by net zero targets) and fluctuating prices, energy security may be undermined if the UK is overly reliant on overseas sourcing.

iv https://www.iea.org

v Figures calculated based upon figures from UK Government Biomass Strategy here. Assuming 18 GJ per dry tonnes of miscanthus and up to 15 dry tonnes per hectare of crop.

# 5.

## Relying on BECCS could deter genuine climate action

There is a significant risk that BECCS (and other NETs) causes 'mitigation deterrence' by allowing Governments to ease off cutting emissions today in exchange for offsetting them in the future.[60] Studies have shown that in scenarios with mitigation deterrence we miss key temperature goals. If we don't treat carbon removals as additional, and they fail to materialise, we risk an extra 1.4°C of warming.[61] Ultimately, separate targets for emissions reductions and emissions removals would ensure that ambition in the latter doesn't undermine ambition in the former.[62]

# 6.

## BECCS could be costly and undermine energy security

**BECCS will be expensive for UK households:** The UK Government's own analysis shows that BECCS could need a return of £179/MWh, perhaps three to four times higher than the return needed by new onshore wind or solar; if this return is not generated by sales of electricity, the difference could well be made up by subsidies from energy bills.[63]

It has been estimated that a BECCS power plant will cost the UK consumer around £31.7bn in subsidy from the UK public to remove 8 $MtCO_2$/yr in the 2030s.[64] The inverse relationship between a BECCS plant's ability to generate electricity and the capture rate of carbon means that if carbon capture is maximised, BECCS plants run at lower energy efficiencies, burning more feedstock to produce the same amount of power than if carbon capture rates were lower. This would require high levels of subsidies for BECCS power production.

**BECCS feedstock is likely to become more expensive:** The bioenergy industry's primary concern for the future is the price and supply of feedstock, largely because the feedstock is the single largest operating cost for bioenergy power plants.[65] Global demand for biomass is expected to increase further, with demand for wood predicted to quadruple by 2050, yet supplies of biomass are expected to come under direct threat from climate change leaving the UK potentially beholden to international markets if BECCS is relied upon heavily.[66, 67]

A report by Chatham House found that scaling BECCS by solely combusting wood pellets to meet the CCC's BECCS 2050 target would require the combustion of more than four times that currently burned at Drax.

# Research Findings

**Given these risks, the objective of the research was to examine whether it is possible to reduce the UK's future reliance on BECCS and still achieve net zero emissions by 2050, whilst understanding the wider environmental and land use implications of these decisions.**

The study used the UK TIMES energy model to examine different scenarios (see Table 1) for the UK's energy system. UK TIMES uses cost-optimisation to find the most cost-effective energy system across the UK while taking into account any other specified parameters.[68] Relevant outputs of the TIMES model were fed into a separate land use model called the Natural Environmental Valuation Net Zero (NEV Net Zero) model,[69] which makes land use choice decisions across each scenario and the ecosystem service values attached to them, across Great Britain only. This study therefore doesn't present implications for land use in Northern Ireland.

The scenarios were chosen to understand what might need to happen across the UK energy system and land use under differing levels of BECCS.[vi] The Reference scenario (REF), which is based on the CCC's Balanced Net Zero pathway, is intended to act as a baseline to which the other scenarios can be compared. Two Alternative Future pathways (AF1 and AF2) were modelled: in these there is a lower reliance on BECCS than the UK Government's Net Zero Strategy. The first, AF1, models a scenario in which there are deeper societal shifts and behaviour change, and the second, AF2, relies more heavily on technological solutions like DACCS. The final scenario (BECCS Failure) closely matches the Reference scenario, but CCS rollout is unsuccessful, meaning that BECCS fails to materialise.

Across the scenarios, there is no explicit modelling of nature restoration or management. Instead, land use changes resulting from increased afforestation (a natural climate solution[vii] including a mix of productive and unproductive broadleaf and conifer trees), bioenergy crops (for BECCS, combined heat and power and unabated bioenergy generation) and renewable technology are modelled and compared to the land use prior to its displacement.

vi The scenarios were developed through a form of morphological analysis which identified a list of energy system factors important in the context of future UK energy pathways, with a focus on BECCS.

vii Natural climate solutions are actions to protect, better manage and restore nature to reduce greenhouse gas emissions and store carbon.

**Table 1 - Scenarios**

| Scenario | Description | Key Features |
|---|---|---|
| **Reference (REF)** | Assumes climate targets are met by a mixture of new technology and afforestation, although the former plays a greater role.<br><br>Reflects (but does not exactly match) the Climate Change Committee's Balanced Net Zero pathway (BNZP) for the energy system. | • Medium levels of innovation<br>• High renewable rollout<br>• New nuclear remains costly and slow to build<br>• CCS rollout successful<br>• Low levels of direct air carbon capture and storage (DACCS)<br>• High levels of BECCS<br>• Afforestation similar level to CCC BNZP<br>• Medium reliance on biomass imports<br>• Public make some but not significant levels of behaviour change |
| **Alternative Future 1 (AF1)** | Societal change: Low reliance on BECCS with significant societal shifts and high levels of afforestation. | • Medium levels of innovation<br>• High renewable rollout<br>• New nuclear remains costly and slow to build<br>• CCS rollout is moderately delayed relative to the reference scenario and so BECCS comes online later<br>• Afforestation ambition is extremely high<br>• Sustainable imports of bioenergy have low availability<br>• Public is willing to make significant levels of behaviour change |
| **Alternative Future 2 (AF2)** | Innovation: CCS is successful, but there is a higher reliance on Direct Air Carbon Capture and Storage (DACCS), with a moderate level of BECCS. Climate targets are met by technical solutions. | • High levels of innovation<br>• High renewable rollout<br>• New nuclear costs reduce<br>• CCS rollout is successful<br>• Afforestation ambition is low<br>• Sustainable bioenergy imports have high availability<br>• Public make some but not significant levels of behaviour change |
| **BECCS Failure** | Based on the Reference scenario but assumes that BECCS fails to materialise, and therefore the UK doesn't meet climate targets. | • Low levels of innovation and large technology challenges are unsuccessful<br>• High levels of renewable rollout<br>• CCS, and therefore BECCS, is unsuccessful<br>• No DACCS<br>• Afforestation similar level to CCC BNZP<br>• Public make some but not significant levels of behaviour change |

# Key Findings

1. **The UK can reach net zero and keep the power on with a much lower reliance on BECCS.**
2. **A lower reliance on BECCS will require greater action to electrify the economy, restore nature, and reduce high-carbon demand.**
3. **If we rely heavily on BECCS and it fails then net zero could be missed altogether and may cost society far more.**
4. **Reducing the UK's use of BECCS frees up more land for nature.**
5. **Decisions in the energy sector generate trade-offs for food production and wider ecosystem services.**

# 1.

## The UK can reach net zero and keep the power on with a much lower reliance on BECCS

The models show that there are pathways to net zero in 2050 that significantly reduce the UK's future reliance on BECCS. The low-BECCS scenario (AF1) deploys about 13 $MtCO_2$ removals from BECCS in 2050, all of which is hydrogen-BECCS [viii] ($H_2$-BECCS) with zero power-BECCS. [ix] This is a 76% lower level of the amount of annual BECCS removals relative to the Reference scenario in 2050, which relies on about 54 $MtCO_2$ (split between power and $H_2$-BECCS). This is a similar level to that set out in the Government's Net Zero Strategy (52-58 $MtCO_2$). In AF1 BECCS cumulatively removes 85.4 $MtCO_2$ by 2050 (i.e. adding up how much it removes each year), which is 87% lower than cumulative BECCS removals in the Reference scenario (649.7 $MtCO_2$ by 2050). This is because BECCS only starts in 2045 relative to 2030 in the Reference scenario. As a result, far lower amounts of biomass overall would need to be burned because BECCS is operating at lower levels and for fewer years. AF2 relies on moderate levels of $H_2$-BECCS removals (30 $MtCO_2$ by 2050), and no power-BECCS removals. This equates to 226.3 $MtCO_2$ of removals cumulatively by 2050. The model's preference for $H_2$-BECCS in both AF1 and AF2 comes from the assumptions made about the ability to electrify different end-use sectors and on capture rates and conversion efficiency for the different technology options. When higher capture rates are assumed, BECCS tends to be deployed for hydrogen production. [70]

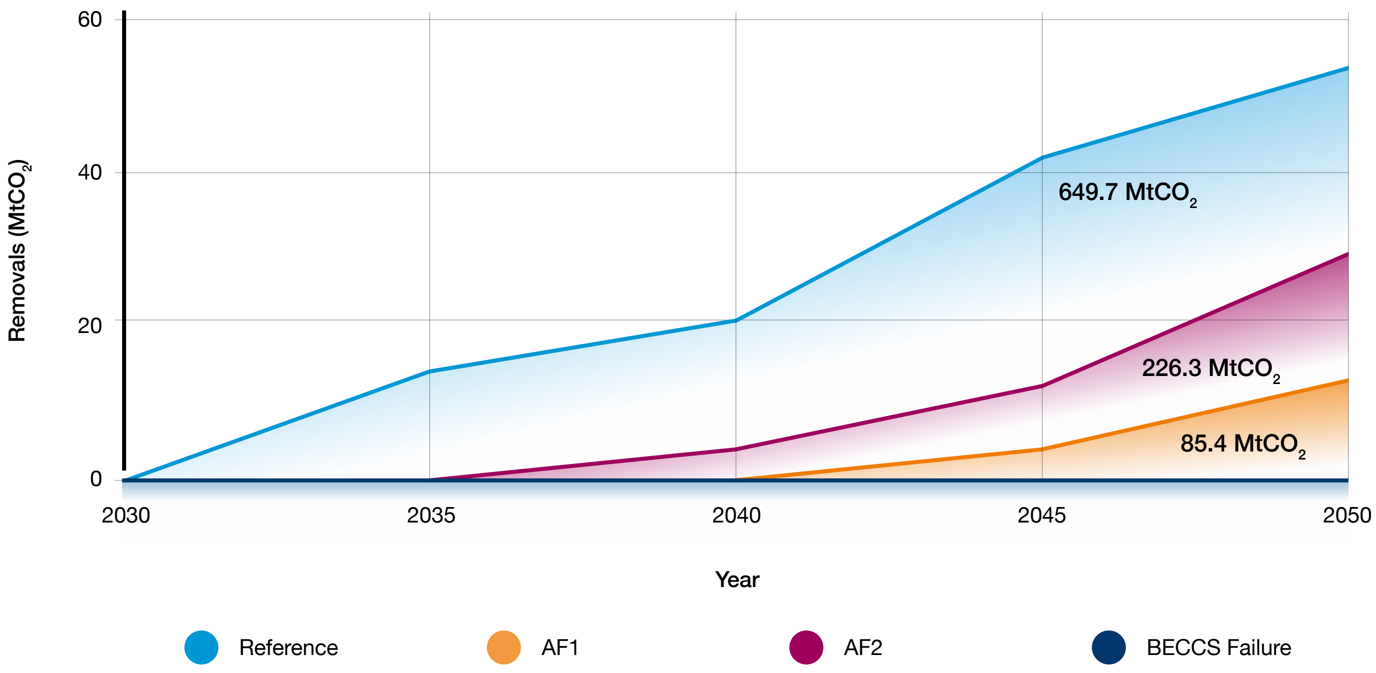
With the right investment, a flexible energy system that uses storage, some electricity imports (at levels similar to the Reference scenario) and renewables is capable of meeting power demand without any reliance on BECCS for power. It is also important to note that the AF1 and AF2 scenarios do not allow for new unabated biomass and existing biomass capacity is retired from 2030 onwards. [x]

viii Hydrogen-BECCS produces hydrogen from biogenic feedstocks that are combined with carbon capture and storage.

ix Power-BECCS produces electricity from burning biogenic feedstocks that are combined with carbon capture and storage.

x The Reference and BECCS Failure scenarios do not have a particular constraint on unabated biomass. AF1 and AF2 do not allow new unabated biomass and allow for existing biomass capacity to be retired from 2030 onwards. Their output drops off by 2035. Contributions from unabated waste biomass plants are unconstrained.

**Figure 2: $CO_2$ removals from BECCS over time across each scenario. Cumulative emissions across the time period are represented by the figure under the line of each scenario. Note that in the BECCS Failure scenario, there are no removals from BECCS before 2050.**




# 2.

## A lower reliance on BECCS will require greater action to electrify the economy, restore nature, and reduce high-carbon demand

Reaching net zero with a lower reliance on BECCS will require a step change in our approach to tackling the climate and nature crises. Table 2, which represents over 99% of all electricity generation in each scenario by 2050, demonstrates how variable renewable energy generation (such as wind and solar) makes up the bulk of installed capacity. The low-BECCS scenario (AF1) reduces demand for electricity relative to other scenarios, but also reaches higher levels of end-use electrification. In particular, wind power is used to fill the gaps when BECCS power is removed from the system. Reducing BECCS will also require extensive innovation and rollout of battery storage solutions to enable higher end-use sector electrification, in addition to some continued reliance on imports of electricity.

**Table 2: Contribution to electricity generation in 2050 across key sources.**

| | Reference | | AF1 | | AF2 | | BECCS Failure | |
|---|---|---|---|---|---|---|---|---|
| **Contribution to electricity generation, 2050** | **%** | **TWh** | **%** | **TWh** | **%** | **TWh** | **%** | **TWh** |
| Solar | 12 | 81 | 11 | 70 | 10 | 78 | 13 | 103 |
| Onshore wind | 9 | 58 | 8 | 50 | 3 | 26 | 16 | 123 |
| Offshore wind | 64 | 431 | 70 | 455 | 70 | 543 | 55 | 431 |
| BECCS | 4 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Imports | 11 | 73 | 12 | 76 | 16 | 120 | 11 | 83 |
| Nuclear | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 35 |
| **Total electricity generation** | | **668** | | **651** | | **767** | | **775** |

At the same time, particularly in AF1, the need to reach net zero with lower levels of BECCS removals means more natural climate solutions, represented by tree cover expansion.[xi] AF1 relies particularly heavily on tree cover expansion to sequester carbon (see Figure 9) with the total area of new tree cover being 2.6 million hectares. This is more than double the level envisaged by the CCC and significantly more ambitious compared to 1.4 million hectares in the Reference scenario. The AF2 scenario relies significantly less on tree cover expansion, with about 0.8 million hectares by 2050 (achieving this through a heavy reliance on technological innovations like DACCS).

As noted above, an important, but often unchallenged assumption is that all biomass is carbon neutral (i.e. the impact on atmospheric carbon of burning biomass is cancelled out by the uptake of carbon as biomass grows). Following this assumption, the Reference case, and the CCC Net Zero Balanced Pathway that it is built upon, do not consider supply chain emissions explicitly. Subsequent scenarios instead recognise that supply chain emissions will reduce the carbon benefit of using biomass systems. They do this by assuming that a share of the carbon contained in the biomass is lost to the atmosphere along the supply chain (e.g. through harvesting, processing, transport, storage). This has the effect of diminishing the carbon benefit from tree cover expansion in AF1 where more tree planting is required for apparently similar levels of effective sequestration as in the Reference case.[xii] Some studies have shown that emissions along the bioenergy supply chain can be between 50-80% of the captured $CO_2$ which translates into carbon removal efficiencies of 20-50% which is less optimistic than the UK Government's Biomass Strategy figures of 65-85%.[71]

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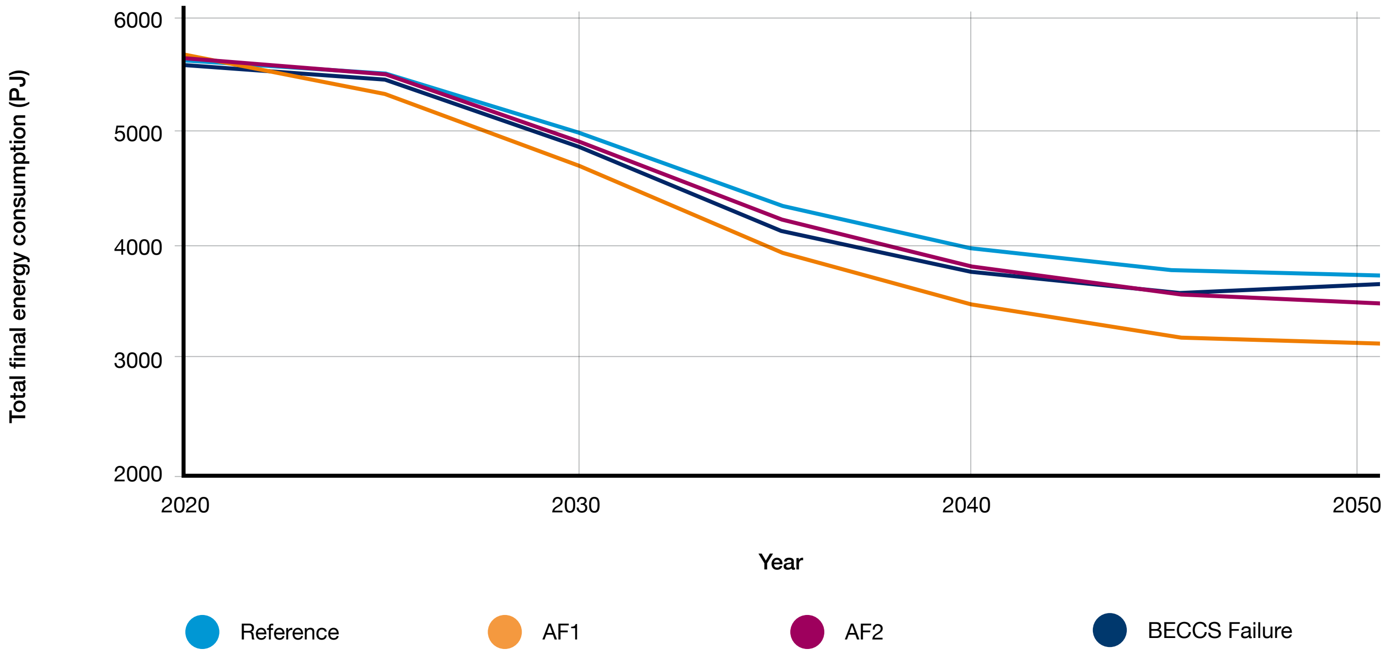
xi Afforestation in UK TIMES refers to the establishment of forests or stands of trees (the model has different tree species available to it). Afforestation is separate from energy-specific options which include eucalyptus, willow, miscanthus, paulownia, sitka spruce and native, grown as dedicated energy crops, short rotation forestry or short rotation coppice.

xii We assume that BECCS failure, AF1, and AF2 respectively have supply chain emissions of 60%, 40% and 30% of biomass' carbon content.

Reducing energy consumption will also be crucial to reducing our reliance on BECCS. This is achieved through energy efficiency improvements and shifts in consumption patterns. In AF1, total final energy consumption reduces by around 45% between 2020 and 2050, whilst in the Reference scenario final energy consumption reduces by about 34% during this period.

**Figure 4: Final energy consumption across scenarios, 2020-2050.**




A fundamental part of reducing the total energy demand across society is consumption and behaviour change. In AF1, it is assumed that high levels of behaviour change are possible. For example, this scenario sees ambitious dietary shifts, right at the upper end of what might be considered feasible, with 67% of people in the UK eating a plant based or vegetarian diet by 2050, compared to 46% in the other scenario and about 8% of people in the UK currently.[72] In AF1, demand for aviation increases marginally between 2025 and 2050, rather than increasing significantly as it does in the Reference scenario.

The lower BECCS scenarios (AF1 and AF2) rely on higher levels of DACCS relative to the Reference scenario, although in AF1 this level is not beyond existing UK Government ambition for this technology. This raises important questions around the technical feasibility of BECCS alternatives and our reliance upon them. There are options to reduce this reliance, and the potential risks of relying on them, but it would require additional emissions cuts in the aviation and agriculture sectors within which behaviour shifts will be important.

## UK diets in 2050 across scenarios

**Figure 5: UK diet in 2050 in AF1 scenario. A plant-based diet refers to a diet sourced entirely from plant-based sources, vegetarian diets do not include meat or seafood, omnivorous diets assume no restrictions on food intake, and a healthy diet refers to the UK Government Dietary Recommendations.** [73]

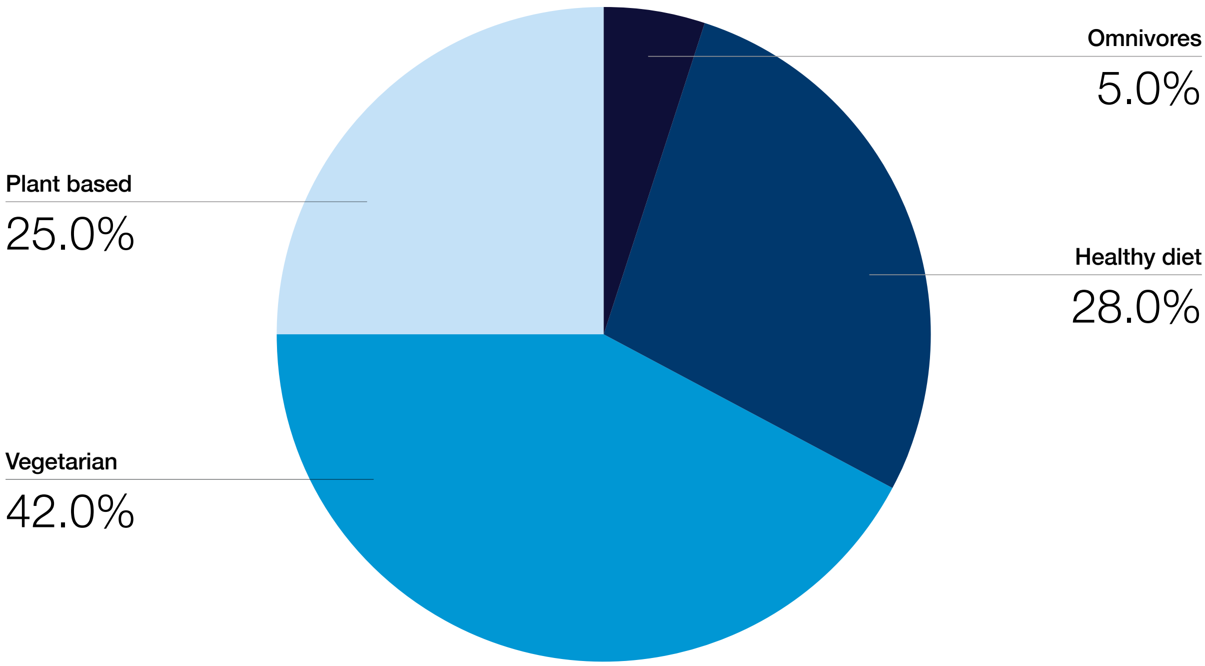
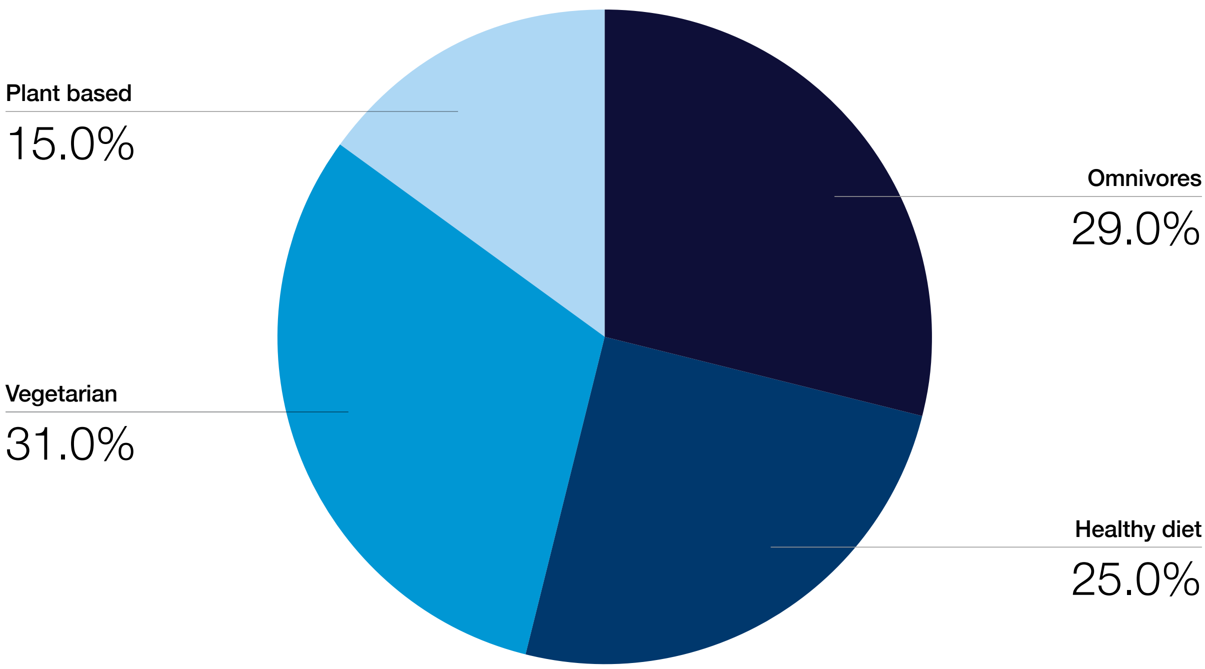



**Figure 6: UK diets in Ref, AF2 and No BECCS scenarios**



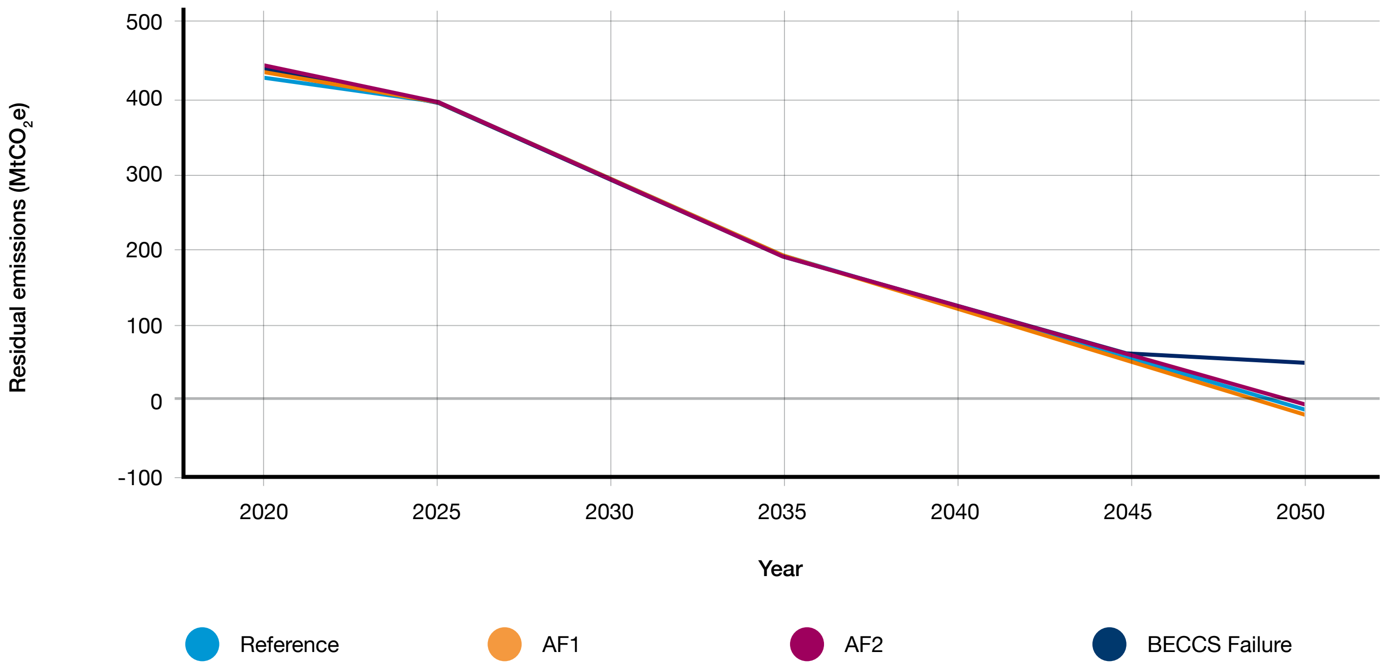
# 3.

## If we rely heavily on BECCS and it fails then net zero could be missed altogether and cost society far more

In a scenario where CCS technology fails to materialise (BECCS Failure), the UK does not achieve net zero by 2050, with excess emissions of 50 $MtCO_2e$ above net zero (see Figure 7). This is because deep emissions cuts do not happen fast enough and too much reliance is placed on BECCS to remove excess $CO_2$ in the future, which then doesn't arrive.

In AF1, BECCS isn't used until 2040 but the scenario still reaches net zero by 2050; demonstrating that the UK can reach net zero if BECCS is not used before this time as long as alternative mitigation measures are taken in the intervening years.

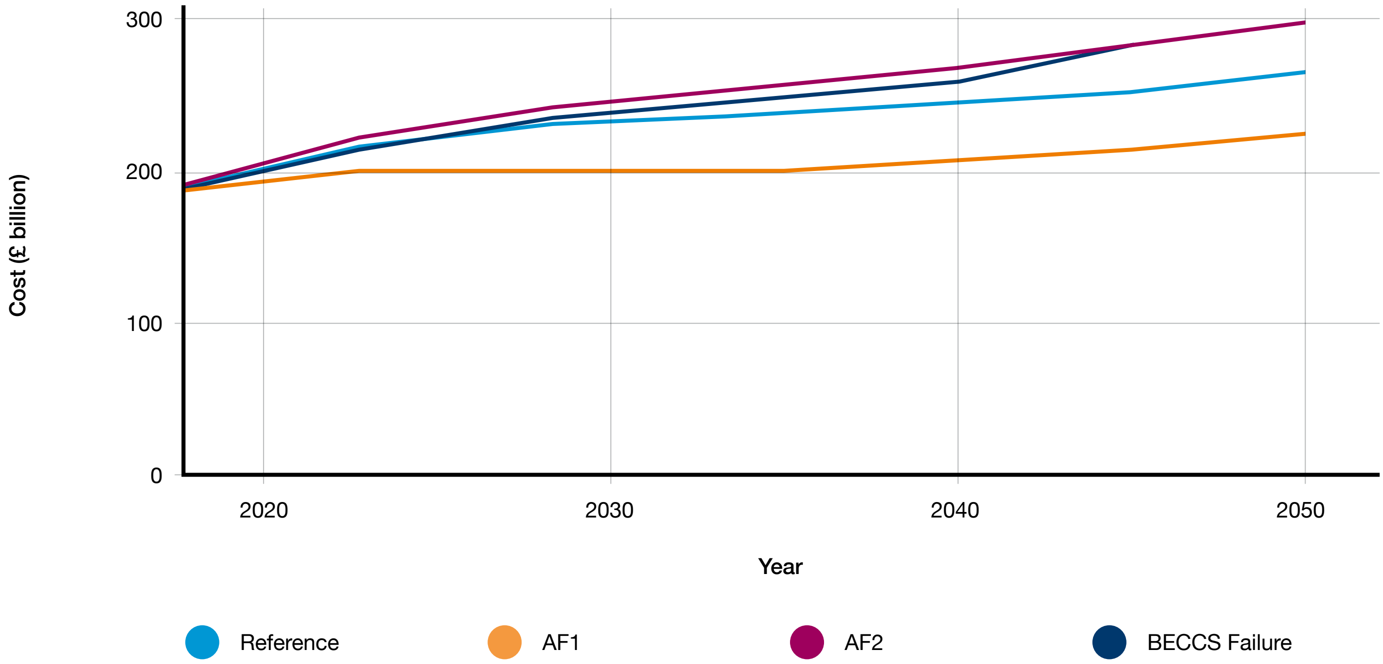
**Figure 7: Emissions pathways across scenarios between 2020 and 2050.**




The risk of missing net zero can be guarded against by using cheaper alternatives to BECCS to cut emissions in the power system sooner. The scenarios which plan for low amounts of BECCS (with fast renewable rollout and reduction of energy demand to reduce the size of the energy system) have the lowest costs. Decarbonising with lower levels of BECCS can be part of an energy system that is £40-60 billion cheaper (per year) than one that includes a moderate to heavy reliance on BECCS. The bill associated with relying on BECCS could otherwise be passed on through energy bills or to taxpayers, including through extremely large subsidies for BECCS.

In the BECCS Failure scenario, the 50 $MtCO_2e$ of residual emissions could equate to a total cost of £20 billion in 2050 [xiii] alone based on future carbon prices, but the model was unable to reflect the cost of the energy system not meeting net zero itself.

**Figure 8: Annual cost of power system across scenarios. The BECCS Failure scenario fails to meet net zero and the model is unable to provide a reliable estimate of the associated costs from 2045 onwards.**




# 4.

## Reducing the UK's use of BECCS frees up more land for nature

### Bioenergy crops compete with food and nature

BECCS requires huge amounts of land, especially if imports of biomass are partially replaced with energy crops grown in the UK. This competes with land that could be used to grow food or restore nature. To reduce the UK land required, the choice is to either reduce our reliance on BECCS or continue to significantly rely on imports of biomass.

To differing extents across each scenario, land of high value for nature is excluded from bioenergy production and afforestation, and in these areas it is assumed that no land use changes take place (Table 2). Peatland is excluded across all scenarios, which comes to an area of nearly 2.2 million hectares. In AF1 the land use constraints are particularly severe and include National Parks and Areas of Outstanding Natural Beauty, which come to nearly 3.4 million hectares of land.

xiii Based on UK Government estimations of GHG emissions values in 2050 (converting the value of a pound in 2020 to 2023 values, in order to account for inflation.

**Table 2: Land use exclusions**

| Scenario | Land use excluded | Exclusion area (ha) |
|---|---|---|
| **Ref** | Peatland, land of high ecological condition[74] (i.e. top 10%) | 3,496,864 |
| **BECCS Failure** | Peatland, land of high ecological condition (i.e. top 10%) | 3,496,864 |
| **AF1** | Peatland, National Parks, Areas of Outstanding Natural Beauty, Agricultural land grades 1-2 and land of high to medium ecological condition (i.e. top 30%) | 9,052,262 |
| **AF2** | Peatland | 2,164,806 |

Without significant imports, the land required in the UK to grow biomass for BECCS is vast. In AF2, where there is a moderate rollout of BECCS relative to existing Government plans and moderate reliance (based on the CCC's Widespread Engagement Net Zero pathway) on solid biomass imports, nearly 1.4 million hectares of land is needed to grow bioenergy crops for BECCS in 2050. This is at the upper limit of the CCC's assessment of available lower productivity land for bioenergy crops, and still leaves us highly dependent on imports.

In the AF1 scenario (13 $MtCO_2$ removal by 2050), the low reliance on imports (which is based on the CCC's Widespread Engagement Net Zero Pathway and so trends to having zero solid biomass imports in 2050) means that by 2050, 800,000 hectares of land are required to grow energy crops in the UK for BECCS, but this land is not required at scale until around 2040-45. This reduces impacts on overseas forests and land by focusing more on growing the biomass the UK needs at home. The Reference scenario requires 215,000 hectares and 800,000 hectares of land to grow bioenergy crops by 2035 and 2050 respectively, but this scenario is heavily reliant on solid biomass imports (based on the CCC's BNZP) so the land use is in reality far greater.

### Land area requirements for renewables are insignificant

The total area of land required for onshore renewables is small (see Table 3). For example, in the low BECCS (AF1) scenario, 72,000 hectares of land is used for solar and 4,800 hectares of land for onshore wind by 2050. Despite this small land take (just 0.46% of total utilised agricultural land), solar and onshore wind contribute to over 18% of electricity generation by 2050. Other energy generation technologies use far less land than bioenergy, which requires millions of hectares.

**Figure 9: Land area use for onshore wind, solar and domestic bioenergy crops across scenarios in 2050 (hectares). For wind and solar, figures are also given for installed capacity (MWh).**

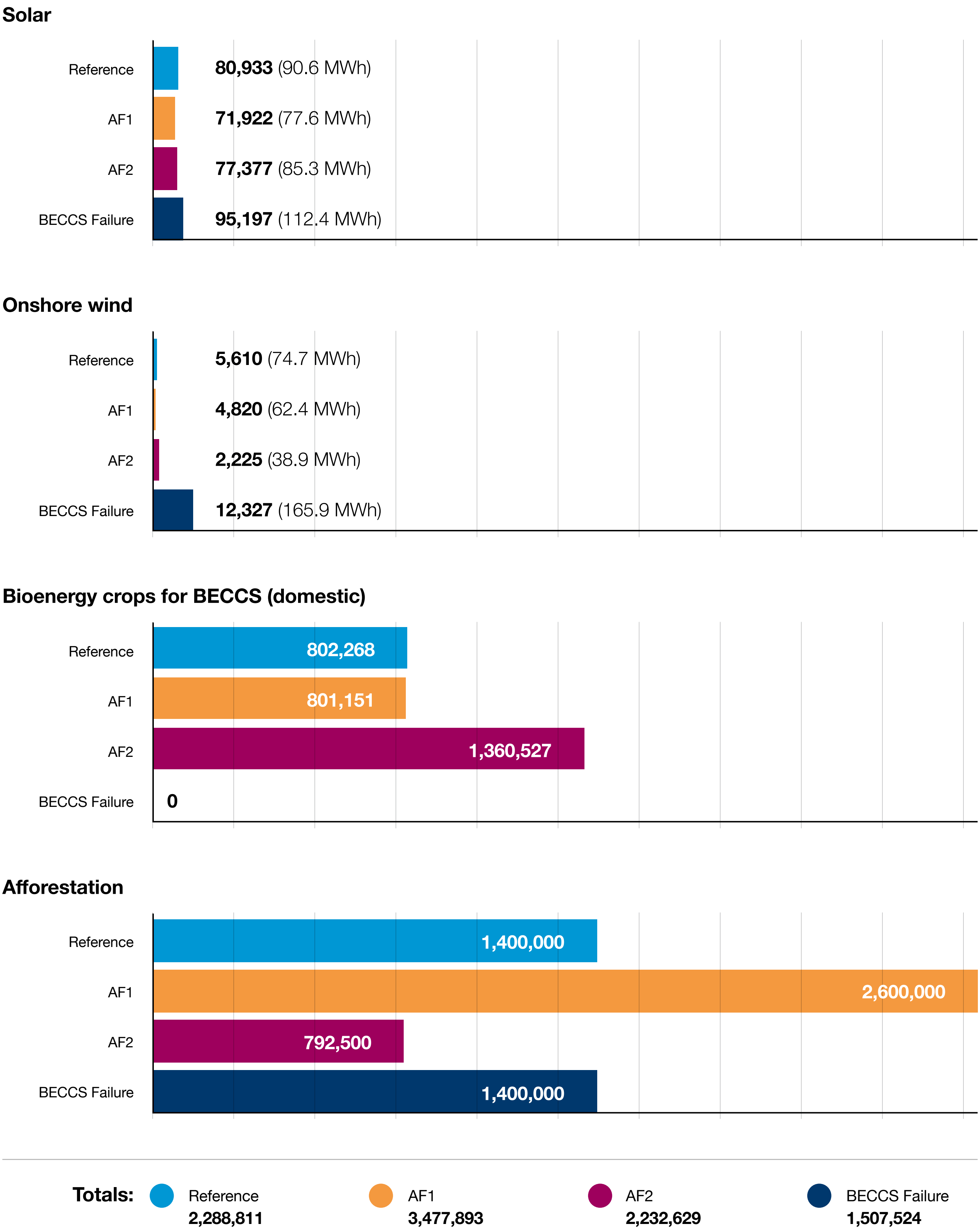
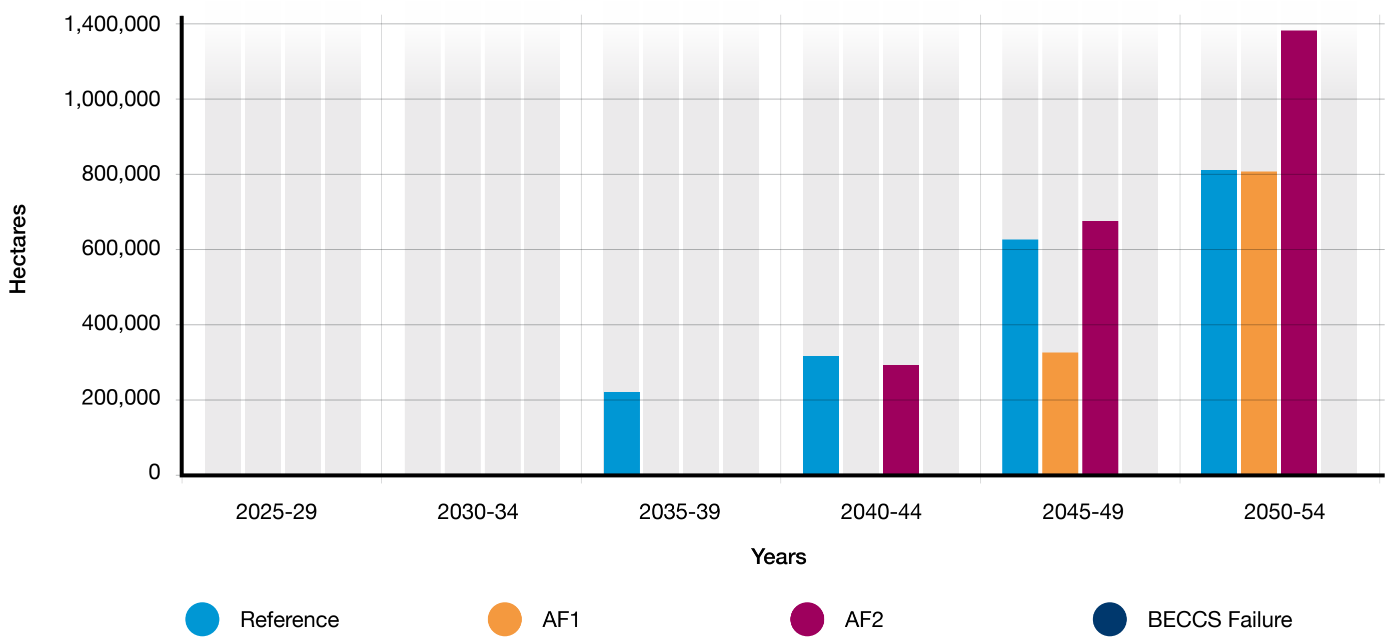


**Figure 10: Total land area required for bioenergy crops for BECCS across scenarios. The totals in each five year period refer to the average land area required each year within that period.**




# 5.

## Decisions in the energy sector generate trade-offs for food production and wider ecosystem services

Overall, the land requirements of nature restoration, biomass, food production and renewable energy generation will need to be carefully considered to minimise trade-offs.

### Ecosystem service and biodiversity impacts

It is beyond the scope of this report to outline in detail the ecosystem service impacts resulting from the land use changes seen in each scenario (namely: tree cover expansion, bioenergy crop planting and solar and wind installation). These results are therefore described qualitatively. Overall, the highest ecosystem service benefits (in terms of reducing flood risk, carbon mitigation, pollination and improving water quality) come from tree cover expansion on what was previously farmland. Some may also come from switching agricultural crops to woody biomass crops like willow coppicing. These accrue owing to the shift from intensive agricultural activities they displace, although the scale of these benefits is dependent on well informed choices about the location of the land use change and the tree species planted.

All the scenarios result in largely positive outcomes for biodiversity (see Table 3). Across the scenarios, afforestation and bioenergy crop rollout improves biodiversity relative to the intensive arable agriculture it displaces domestically, although this doesn't account for the impacts of offshoring food production overseas. Bioenergy crops however are not always the optimum land use for biodiversity, and futures with lower energy demand, greater dietary shifts and lower BECCS would enable spare land to be restored for nature, with accompanying biodiversity and climate benefits.

**Table 3: Biodiversity outcomes across scenarios. The model tracked the presence or absence of over 800 species within 1km cells across Great Britain. A positive change can be interpreted as there being more cells where a species is present after the scenario land use change than without it. Likewise a negative change is where a species is present in fewer cells after the land use changes than in the baseline.**

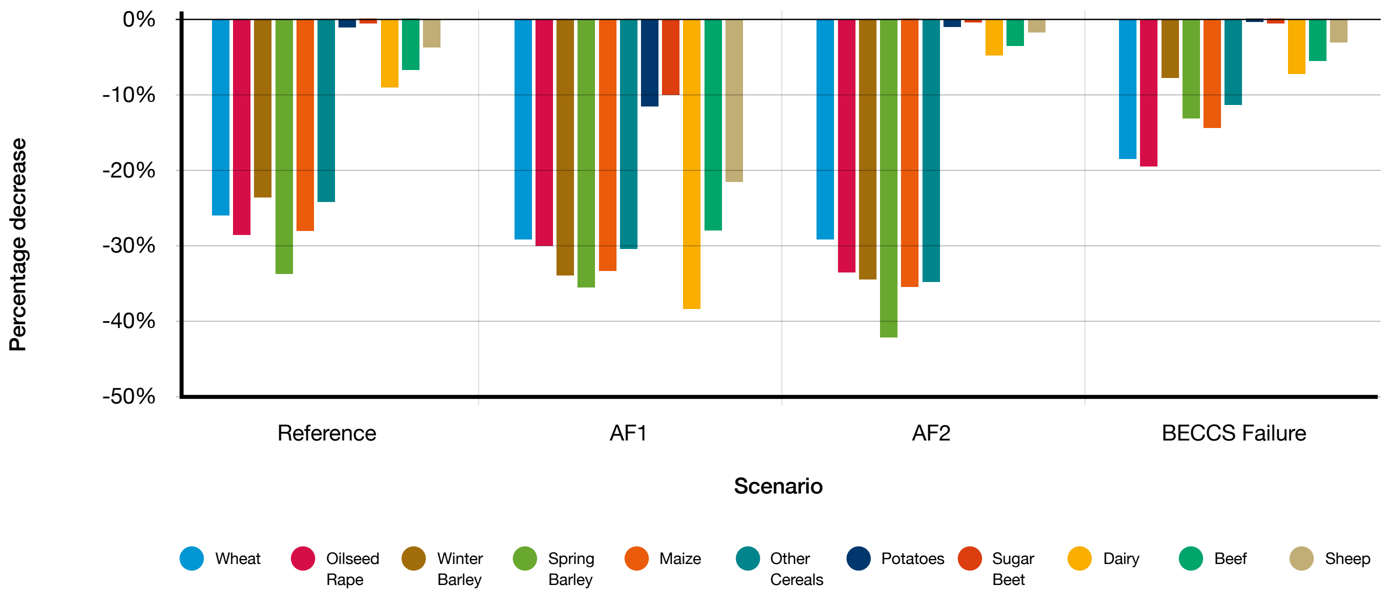
| Biodiversity | Reference | AF1 | AF2 | BECCS Failure |
|---|---|---|---|---|
| Positive | 736 | 754 | 727 | 740 |
| No change | 45 | 31 | 50 | 49 |
| Negative | 33 | 29 | 37 | 25 |

### Food production is impacted across all scenarios

The inverse of this is that displacing food production for afforestation or bioenergy requires higher imports of food from overseas, the production of which the UK has less control over and which may be produced to lower environmental or animal welfare standards.[75] Figure 11 shows the trade-offs for food production in the UK, demonstrating that all scenarios result in a reduction in food production, particularly for arable crops due to arable land being displaced by tree cover expansion and bioenergy crops to differing extents (see explanation below).

AF1 saw the largest decrease in production in 2050 relative to 2020 across the scenarios due to the significant levels of tree cover expansion and low reliance on biomass imports. It also sees higher reductions in livestock production due to the dietary shifts seen in this scenario towards more plant-based diets.

**Figure 11: Food production, percentage difference in 2050 compared to 2020 across all scenarios.**




The land use model accounts for the displacement of GHG emissions from the offshoring of food production overseas (and assumes that domestic and overseas emissions from farming are largely equivalent). As a result, to reach net zero whilst optimising for costs, when locating land for bioenergy crops and tree cover expansion the model prioritises arable farmland over pasture. Unlike the other scenarios, in AF1 the location of forestry is roughly equally split across both pasture and arable land, possibly because the area of land excluded from tree cover expansion is so significant in this scenario. Multiple factors contribute to the prioritisation of arable over grassland, including the higher carbon costs of disturbing grassland. When the model doesn't account for GHG emissions displacement overseas, it tends to prioritise the conversion of pasture for bioenergy crops and forest because there are greater emissions reductions available from removing livestock than removing arable land from production. Despite this, AF1 prioritises the conversion of arable land more in this scenario. This approach differs from that taken in other recent land use modelling such as the RSPB's Land Use Scenarios Project, which prioritises lowest yield potential land for conversion to nature-based solutions (NbS) first (see Box 3).

The stringent land use criteria in AF1 result in over nine million hectares of land being excluded from tree cover expansion. Much of this area, including in National Parks, is low productivity land (including farmland) that would be suitable for ecosystem-restoration, for example through planting native and broadleaf woodland or restoring peatland and saltmarshes.[76] If applied at scale, this would bring significant climate and biodiversity benefits and could reduce the need for afforestation on arable land.

# Discussion

## The UK can, and should, reduce its reliance on BECCS

This study has shown that decisions in the energy and land use sectors will result in trade-offs that will be difficult to manage. However, we know that it is possible to reach net zero with far lower reliance on BECCS than currently planned.

This is important because there are significant risks to relying on BECCS at scale (see Section: **Why is Relying on BECCS Risky?**). If BECCS fails to materialise, or is not net negative, the UK could miss net zero and significantly increase the costs of the transition. Even a limited reliance on BECCS requires significant land use to generate wood from forests or grow energy crops, either domestically or overseas. In both cases this means trade-offs with nature restoration and food production. Moreover, future negative emissions will be worth far less if we have already blown past climate tipping points; the priority must be immediate deeper decarbonisation.

To achieve this we will need to go further and faster in other proven decarbonisation methods, but this must be done in a way that is good for biodiversity and society at large, and ensures that those on the lowest incomes are not penalised. By reducing our reliance on BECCS, the UK could free up billions of pounds of subsidies that can be redirected towards measures that genuinely help people's pockets, nature and the climate. It has been estimated that Drax's proposed BECCS plant will require £31.7 billion in subsidy which could instead be spent across three main categories.[77]

The first is to increase investment in NbS to enable the protection and restoration of a wide range of ecosystems. This investment would enable the delivery of a vast scope of ecosystem services like climate mitigation and adaptation, in addition to wider economic benefits like job creation.[78] For every £1 invested in tree cover expansion, an average of £2.79 is estimated to be returned in quantified economic and social benefits.[79] Even higher returns can be expected from other NbS that provide additional benefits, such as peatland restoration which studies have found to return as much as £5 for every £1 spent.[80] Restoring nature, or rewilding, just 5% of the UK could provide up to 20,000 jobs.[81]

Secondly, investing more in renewable technologies, like wind and solar can help to bring down consumer prices, improve our energy security and reduce the pressure the UK places on its land relative to bioenergy. This investment must be coupled with power market reform so that the falling cost of renewables is reflected in household bills instead of remaining coupled to fossil fuel prices.[82] These technologies, alongside innovation in storage and energy efficiency, have the potential to satisfy a significant part of the UK's energy demands by 2050.[83] None of the scenarios relied on significant investments in new nuclear capacity to get to net zero, which aligns with recent research showing that new nuclear capacity is only cost-effective if ambitious cost and construction times are assumed, competing technologies are unavailable and interconnector expansion is not permitted.[84] Challenges exist but focussed power sector studies suggest that existing technology could allow for power systems based on high levels of variable renewable energy.[85]

The final category is demand-side shifts and behaviour change. For example, if accompanied by smart land use policy, a wholesale shift towards healthy and sustainable diets could free up land for nature and reduce pressure on our health service. Making the 15% wealthiest and most frequent fliers who make up 70% of flights pay more for flights would distribute the costs of air travel more fairly, limit demand in line with cutting emissions and ensure that those on lower incomes can fly when they want to. [86] Furthermore, low carbon technologies and energy efficiency measures such as home insulation and heat pumps have the potential to save UK households money on their energy bills, in some cases up to £2,300. [87, 88]

The scenarios in this study range in their ambition on energy demand. The most ambitious scenario (AF1) reduces final energy consumption by 45% between 2020 and 2050, but reductions in demand of beyond 50% by 2050 are achievable with the right policies. [89] The UK Government has briefly considered the benefits of reducing national energy demand for our ability to reach net zero, however, there is a lack of a clearly defined strategy, especially since the dismantling of the Energy Efficiency Taskforce. [90] There is also limited focus on behaviour change to cut emissions, despite the fact that both will be necessary to meet net zero and could mitigate against the risks associated with NETs. [91]

### The UK four-country context

In the UK, market support for power generation and regulation of the gas and electricity grids are reserved to the UK Government and Ofgem respectively, and this will be the case for BECCS. However, particularly on biomass supply there are policy levers that devolved Governments can pull, including on agricultural support schemes and environmental regulation. In addition to meeting their own biomass requirements, there are questions around whether Wales, Scotland and Northern Ireland may be required to provide some of the biomass supply for the UK Government's reliance on BECCS which raises challenging questions around land use and availability across the UK.

## Decisions in the energy system lead to trade-offs in land use

This study underlines the fact that what the UK chooses to do in the energy sector has significant implications for land use. Overall, more BECCS means less space for nature and for growing food. Across all scenarios, and particularly where the model relied on domestic production, bioenergy crops result in arable farmland being displaced, resulting in more food being imported from overseas. Although bioenergy crops, such as willow in short rotation coppices, can deliver ecosystem services and improve biodiversity relative to intensive arable production domestically. [92] However, to reduce the trade-offs with food and nature, they should not be grown in areas with high (or potentially high) biodiversity value, should not replace food production on high grade agricultural land, and should be weighed up against the benefits of alternative land uses like native broadleaf woodland. So far, there has been very little uptake of dedicated bioenergy crops in the UK for unabated biomass generation, but the UK Government's recent Biomass Strategy didn't set out ambitions for the UK to reverse this trend.

## Box 3:
## The RSPB Land Use Scenarios Project [93]

The RSPB Land Use Scenarios Project (LUSP) explores trade-offs in achieving net zero from UK land. This work created a set of spatially explicit scenarios to reflect different GHG emissions reduction strategies within the land sector.

The work found that scenarios with more NbS such as habitat creation and restoration were more effective at reducing GHG emissions. However, LUSP showed how even under the most ambitious scenario, net zero within the land sector alone will be difficult to achieve and sustain. The best performing scenario reduced net GHG emissions from the land sector by over 99% by 2050.

It modelled bird habitat as a proxy for biodiversity more widely, finding that when NbS is rolled out birds gain suitable habitat, although some farmland species may be negatively affected.

Although the modelling prioritised land with lowest yield-potential first, the trade-offs of increased nature rollout included reductions in food production (as much as 21% in the best-performing scenario), which could be limited through food system transformations such as dietary shifts, reductions in food waste and yield increases.

In AF1 there are extremely high levels of tree cover expansion, with planting rates required that are significantly higher than the Reference scenario and existing UK tree planting targets. This expansion would be difficult to achieve and would invariably displace some food production. [xiv] Tree cover expansion can provide significant benefits for people and for nature, but this depends on the desired objective, species mix and location. Ultimately, the extent of afforestation required to reduce the reliance on BECCS highlights the decisions that the UK faces.

Although afforestation rates in the AF1 scenario are extremely ambitious, Defra recently identified 3.2 million hectares of ‘low-risk’ land suitable for conversion to woodland in England alone. [94] A recent separate estimate indicates that this value may be optimistic, placing the area of land suitable for woodland across the UK as two million hectares (although this rises to 4.6 million hectares if carbon-rich organo-mineral soils are in scope). [95] More generally, given that only 43-51% of protected sites are estimated to be in favourable condition, and that only 4.9% of UK land area may be effectively protected for nature, there are significant opportunities for NbS rollout beyond tree planting, including within National Parks and Areas of Outstanding Natural Beauty, which make up over 20% of the UK’s total land area and are highly degraded. [96] For example, 80% of the UK’s peatlands are degraded and emit enough carbon to negate the entire carbon benefits of forests across the UK each year; restoring these areas would bring enormous climate benefits not accounted for in the modelling. [97, 98] This might reduce the need for tree cover expansion on farmland seen across these scenarios.

xiv UK Government tree planting targets are 30,000 hectares from March 2025. To plant 2.6 million hectares of trees by 2050 would require on average just under 100,000 hectares of tree planting each year until 2050.

Planting trees and restoring nature in some of the least productive areas of the UK, often protected areas, could yield significant benefits for climate and nature. Recent research by Green Alliance has shown that by prioritising rewarding farmers for doing this, often alongside ongoing food production businesses, the UK could reduce taxpayers' costs and improve biodiversity more than in scenarios with large quantities of bioenergy crops.[99] This approach assumes a direct link between diets and livestock production in the UK (i.e. livestock are not exported in response to lower UK demand), resulting in land being made available as diets shift. This means additional and complementary policy is required to reduce the impact of domestic and overseas food production by keeping productive arable land in production. This includes policy to reduce food waste, shift from growing animal feed crops to crops for human consumption and generate yield improvements.[100] It would also require the spatial prioritisation of land through the implementation of a Land Use Framework and progressive trade deals that prevent British farming standards being undercut from overseas production.

As with additional recent research by the RSPB, this study found that the total land area required for renewables by 2050 is small relative to other land use but contributes significantly to electricity generation by 2050.[101] For example, solar and onshore wind in AF1 use just 0.46% of total utilised agricultural land in the UK, yet contribute to over 18% of electricity in 2050. A further recent study has shown that Britain could meet its entire energy needs (and ten times current electricity demand) with wind and solar alone by 2050 if the grid was sufficiently upgraded.[102] In contrast, non-waste bioenergy requires hundreds of thousands of hectares (either domestically or overseas) yet contributes little to overall electricity generation (about 13% in 2021).[103] Where it can be done to reduce the negative and, where possible, enhance the positive impacts on nature, renewable rollout should be widely prioritised. Ultimately, a high reliance on BECCS reduces the resources the UK has available to put towards genuinely low-carbon renewables and towards nature and food production.

## The UK has a responsibility to take a precautionary approach to BECCS

### Significant costs

The economic costs of BECCS are significant, and these costs will ultimately fall on UK households and businesses, probably through new subsidies paid to bioenergy companies.

The Government wants to pay BECCS generators a guaranteed price (through a Contract for Difference) for both electricity and stored tonnes of carbon. This will mean that the poorest households pay more - because these subsidies are added to energy bills, and poorer households tend to spend a much greater share of their income on energy than richer ones.[104] These subsidies would need to be big - the Government's own analysis shows that BECCS could cost £179 per unit of energy generated, which is around three times more expensive than wind or solar, and more expensive than new nuclear power.[105] It has been estimated that Drax's proposed BECCS plant will require £31.7 billion in subsidy.[106]

As well as direct subsidy, this analysis has also shown that it can be cheaper for the overall energy system to reach net zero with a reduced reliance on BECCS (perhaps £40-60 billion per year less) than one that includes a moderate to heavy reliance on BECCS.

**The need for a strong regulatory and sustainability framework**

However, to reach net zero, some BECCS in the UK may be necessary. If the costs of BECCS are to be justified, it must operate within a robust and enforced regulatory framework that ensures it delivers genuine negative emissions whilst not transgressing key ecological planetary boundaries. The UK Government's 2023 Biomass Strategy does acknowledge sustainability as the primary principle for biomass, and partially recognises the fact that the methods and criteria used to assess sustainability do not take into account wider factors like indirect land use, resource competition and a full assessment of biogenic carbon emissions.[107] The UK sustainability criteria should be amended to reflect these factors and feedstocks which present a higher risk in these areas should have greater controls applied to them.[108] The UK's Land Use Framework will be pivotal in understanding where domestic biomass could be grown.

This report proposes a precautionary approach to BECCS. It has laid out many of the difficulties still facing large-scale rollout of BECCS in the UK and whilst many of these challenges may be overcome eventually, there is uncertainty around the future performance of BECCS.[109] For example, although the UK Government's Biomass Strategy assumes carbon removal efficiencies of between 65-85%, recent studies have estimated that emissions along the bioenergy supply chain can be between 50-80% of the captured $CO_2$ which translates into carbon removal efficiencies of 20-50%.[110] If BECCS comes online later than anticipated (as with the low-BECCS scenario) or biomass supplies are constrained (as modelled within the recent UK Government Biomass Strategy), it is only additional action in the intervening years that will enable us to still reach net zero. Studies have shown that even if the risk of BECCS failure is ~20%, the case for additional mitigation prior to 2030 rises steeply.[111] This is pertinent to the UK's wider approach to all NETs, including DACCS.

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# Key Recommendations

## 1) Apply a precautionary approach to BECCS with strict limits on its rollout

- **Constrain BECCS to the levels of genuinely sustainable feedstock available,** prioritising genuine wastes, by-products and residues sourced in the UK first.

- **Subject all feedstocks to a sustainable biomass hierarchy and more ambitious and stringent sustainability criteria than currently used.** [112] The criteria should include a wider scope of environmental factors than what is currently included (to incorporate soils, water resources etc.) as well as a wider assessment of the environmental (and social) risks associated with a feedstock than purely life cycle analysis. This means an assessment of resource and land competition (including indirect land use change). It should also account for carbon payback periods, which should be explicitly ensured to be Paris Agreement compatible.

- **The UK Government should rule out eligibility for energy subsidies of any wood from forests (including roundwood, thinnings, branches, bark, stumps).** Moreover, there should be no imports of any wood from primary forest whatsoever.

- **BECCS projects must be effectively regulated with stringent monitoring and verification across the entire supply chain.** The findings suggest that the UK may not be able to achieve net zero without BECCS and so it is important that BECCS as a technology succeeds. This will require effective regulation from biomass sustainability through to the permanence of carbon storage to ensure that negative emissions are delivered without sustainability breaches.

## 2) Eliminate unabated biomass generation

- **Unabated biomass generation should not be supported by public finances after 2027.** The CCC has been clear that continuing to burn trees for energy is bad for the climate and for people's pockets, and this analysis has shown it is not necessary to meet net zero. BECCS plants that are not capturing at a suitably high rate of 90-95% should not receive any subsidies for electricity generation.

## 3) Invest in nature restoration and reward farmers for protecting nature and storing carbon

- **In the right locations, farmers should be rewarded for planting trees and restoring nature on their farms.** Large scale afforestation, whilst it can be highly beneficial for nature, can undermine UK food production and so spatial prioritisation will be crucial; areas of low-productivity should be prioritised (alongside dietary shifts, improving crop yields, reducing food waste and prioritising crops for human food production over livestock feed production). However, this should avoid priority habitats where possible.

- **Only incentivise bioenergy crops on low productivity land and within nature-friendly farming systems.** Although genuine wastes and residues should be prioritised via a sustainable biomass hierarchy, there may be some value in growing a limited area of bioenergy crops domestically. This should never be in areas with high value for nature and, to assist with this, the upcoming Land Use Framework should identify where the optimal locations might be and how much could be grown.

- **Invest more to restore priority habitats and protect wildlife.** According to calculations by Wildlife and Countryside Link, the Government is not investing enough per year to guarantee the restoration of nature and habitats. This means natural habitats that can store carbon, provide health benefits, and support wildlife, will be left in a poor state or not created. [113]

## 4) Go much further and faster on decarbonising across the economy and reducing energy demand.

- **Speed up the rollout of onshore wind and solar whilst avoiding harm to nature as far as possible.** This should be accompanied by electricity market reform to ensure households begin to benefit from the lower costs of renewables.

- **Implement a clearly defined and ambitious strategy to reduce demand for energy substantially by 2050.** [114] This could include efforts to reduce the number of flights taken each year by those who fly the most, shift diets to those that are more sustainable and healthier, and insulate homes across the country.

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## Acknowledgements:

This report was written based on new research developed between November 2022 and October 2023 by the researchers at University College London, University of Exeter, and University of Southampton who are listed hereafter: Oliver Broad, Isabela Butnar, Brett Day, Gemma Delafield, Alison Fairbrass, Rob Holland, Seokyoung (Chris) Kim.

The research team developed new modelling, took part in structured discussions, and offered feedback around the role BECCS may play in future UK Energy Pathways to net zero. The interpretation and write up contained in this report, however, represent the views or opinions of RSPB and WWF.

Further details on the modelling work will be presented as a journal paper to be submitted for publication by the research team in early 2024.


Published in November 2023 by WWF-UK and RSPB.

**WWF-UK:** Leanne Atkinson, Jo Furtado, Isabella O'Dowd
**RSPB:** Mair Floyd-Bosley, Alex Mackaness, Matt Williams
Funding has been provided in part by the Climate and Land Use Alliance.
The authors are solely responsible for the content.

**Design:** Clean Canvas Studio
www.cleancanvasstudio.co.uk