

Each year humans pump the equivalent of 35 billion tonnes of carbon dioxide into the atmosphere.

This means we may reach 1.5 degrees in five years' time.

Against this grim background, researchers have modelled hundreds of scenarios for stabilising the climate, taking both socio-economic factors and climate science into account. Most scenarios show that it is too late to keep global warming below two degrees let alone 1.5 degrees simply by cutting emissions. Many therefore put their hope in future technologies to remove more carbon dioxide from the atmosphere than future economies will emit. But such hope could delay action.

To achieve most 1.5 degrees scenarios, we need to remove between 100 and 1000 billion tonnes of carbon dioxide from the atmosphere. There are no negative emissions technologies that work at such a scale, and those being trialled are likely to have damaging environmental, social and economic impacts. We cannot, therefore, prioritise non-existent, hypothetical negative emissions technologies in favour of full and fast decarbonisation.

This briefing note is based on a literature review of studies on BECCS. It outlines six reasons why policy makers should exclude it from decarbonisation pathways for 2050 or beyond.

BECCS : A TEMPTING CHIMERA...

In its simplest form, BECCS is the hope that we can bury emissions from burning biomass underground. Proponents say that since trees and agricultural crops naturally remove carbon dioxide from the air, burning them to produce energy, and then capturing and storing the resulting emissions, should deliver negative emissions.

But the emissions would only be negative if the plant growth is additional to existing or foreseen plant growth, as the plants would have removed the carbon dioxide anyway. If the plants are not new, the overall emissions balance could be at best near zero but not negative.¹

But even that best case scenario doesn't stand up to scrutiny. The whole BECCS processing chain is energy intensive and leaks so much carbon dioxide (see figure), that it might not even achieve zero emissions in some cases. The level of emissions from BECCS would vary widely, depending on the feedstock used, the land use changes involved, and a variety of other issues.

One of the most controversial of these issues is the source of proposed future additional biomass. According to the European Academies' Science Advisory Council (EASAC), even in the best case, "BECCS deployment at the huge scales envisaged in many scenarios may greatly overestimate our collective ability to manage carbon cycle flows, thereby risking doing more harm than good." They add that it "could potentially help mitigate climate change, but at the expense of further exceeding the planetary boundaries related to biosphere integrity, land use and biogeochemical flows, while bringing freshwater use closer to its boundary."

Today, despite more than a decade of BECCS hype in political debates (notably pushed by fossil fuel interests), there are no operational BECCS facilities claiming to produce substantial negative emissions anywhere in the world. Only half a dozen demonstration projects exist, with only one, a United States of America (US) ethanol-from-corn plant funded by the US Department of Energy, claiming to remove more than one million tonnes of carbon dioxide per year (see Box: Decatur project). Many scientists have highlighted feasibility constraints that would make it unlikely to ever work, at least not on the scale foreseen. On 27 February 2022, EASAC updated its previous BECCS assessment and insisted that "there are substantial risks of [BECCS] failing to achieve net removals at all, or that any removals are delayed beyond the critical period during which the world is seeking to meet Paris Agreement targets to limit warming to 1.5–2°C."

¹ Additional carbon dioxide removals mean an increase in the amount of carbon stored in ecosystems annually.

1 – BECCS produces significant emissions

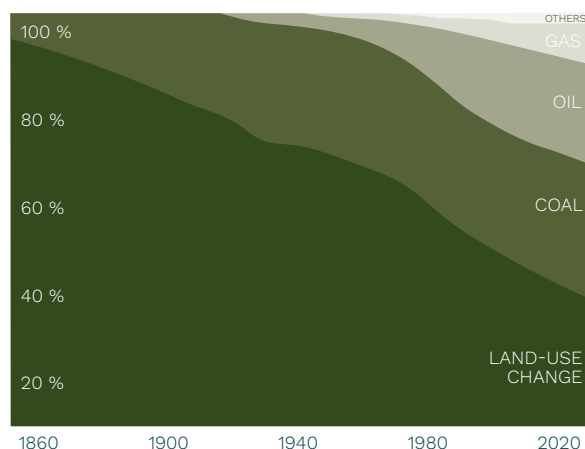
BECCS is proposed as a solution based on the assumption that bioenergy would be carbon neutral.² But this assumption is incorrect, notably because of emissions from land use and forestry: today, 30 per cent of carbon dioxide in the atmosphere came from land use change (including deforestation), not fossil fuels (see Figure: Cumulative Global Carbon Dioxide Emissions).³

Even in a best-case scenario where bioenergy was only produced from 'additional biomass sources', carbon capture and storage (CCS) only captures emissions released from burning biomass. No mention is made of the indirect and supply chain emissions related to foregone sequestration, biomass production, harvest, transport, refining, capturing and storing. These release considerable emissions.

THERE ARE THREE MAIN TYPES OF EMISSIONS TO CONSIDER:

- **Emissions from logging (which reduce the carbon stock in trees and soil).** There is a significant time lag between the moment of harvest or combustion and the assumed regrowth. The general rule is that if you cut a forest down, it takes the same amount of time it took to grow for it to return to its previous level of carbon storage. Even this only works if a significant proportion of wood is left on site to decompose to allow forest regeneration (some carbon from the logged trees is already re-emitted at that point). On average this would be between 50 and 120 years, but there is also the possibility that a forest is never able to host as much carbon as before, especially if the logging method damages soils and depletes it of nutrients. It is also important to remember that due to **the unprecedented climate crisis, future growth conditions are unknown**.

In addition, while a forest left standing continues to remove carbon, the moment it is cut down, sequestration stops. **The lost sequestration of a harvested forest is known as foregone sequestration.** Without bioenergy demand and



CUMULATIVE GLOBAL CARBON DIOXIDE EMISSIONS: SHARES (ADAPTED FROM GLOBAL CARBON PROJECT)

the associated production of bioenergy crops, there could be larger climate benefits from letting forests simply get older, storing more carbon rapidly and becoming more resilient to the effects of climate change. Using timber for material uses, and not energy, would also contribute to storing carbon rather than emitting it.⁴

- **Emissions from destructive land use changes.** Cultivating dedicated biofuels crops can compete with food production and thereby trigger more deforestation, with forests being converted to agricultural land being one of the largest global drivers of climate change. Growing bioenergy crops could add to this problem and accelerate warming. In addition to direct land-use change, increasing demands for land can drive indirect land-use change (ILUC). For example, if an energy crop such as willow is planted to meet demand for wood chips, and it displaces agricultural land for food production, the food producer needs to find other land, which can drive deforestation.
- **Emissions from the production of biomass, the supply chain and CCS.** The growth of biomass in dedicated crops can lead to a large increase in fertilizer use. Nitrous oxide (N₂O), which is released in fertilizer creation, storage and use, is particularly problematic as it has a global warming potential up to 300 times higher than carbon dioxide. Scientists trying to quantify the global warming effect of

² Carbon neutrality refers to a concept where a measured amount of carbon released is balanced with an equivalent amount sequestered.

³ The European Academies Science Advisory Council, UK government agency Forest Research, Chatham House and 800 scientists have highlighted that burning forest biomass is not carbon neutral. Read also [Fern's briefing on the energy use of woody biomass](#).

⁴ Land use change can also increase warming due to a change in 'albedo' – whereby light-coloured or less densely vegetated surfaces which reflect more light to space are replaced with darker surfaces and thus absorb more warmth.

increased use of N₂O have shown that it can be equivalent to between 75 and 310 per cent of the carbon stored in trees. Fertiliser use alone could turn bioenergy into a source of greenhouse gas even before harvesting and combustion take place. Other concerns include that the CCS technology itself requires large amounts of energy to compress the carbon dioxide and inject it deep underground. The additional fuel required when CCS is applied is up to 31 per cent for coal fired installations, meaning any BECCS operation will need to use at least 31 per cent more biomass for the same energy output as a non-BECCS power plant. There is also a risk of carbon dioxide leaks from CCS sites.

The weight of biomass means that supply chain emissions can be significant. In the case of dedicated

bioenergy crops, emissions from transport, processing and using CCS technology already represents 64 per cent of all carbon stored. For one tonne of carbon dioxide sequestered and stored underground, emissions from the supply chain would amount to 1.11 tonnes of carbon dioxide.



BURNING WHOLE TREES FOR ENERGY IS NOT CARBON NEUTRAL. POWER PLANT IN BARDEJOV, SLOVAKIA. PHOTO: FRED PEARCE

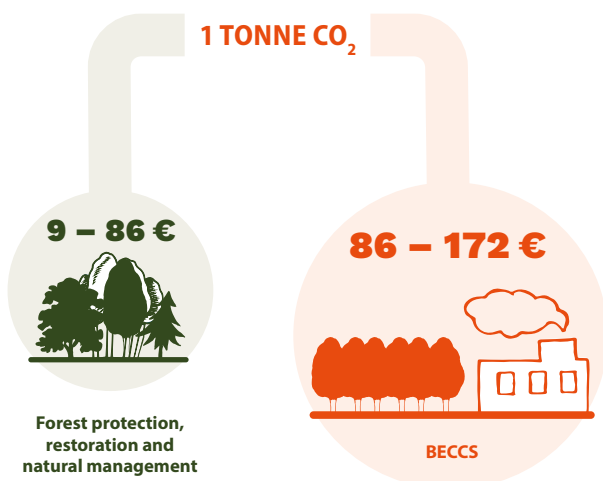
2 – BECCS has technical barriers and is prohibitively expensive

Most scenarios for keeping global warming to 1.5 degrees require BECCS to be available and functioning on a gigantic scale from mid-century onwards. There is an implicit assumption that BECCS can be deployed at an extremely rapid pace, but there are significant questions about feasibility, scale and cost.

Costs of BECCS are difficult to estimate as they depend on the price of biomass feedstock, CCS components, infrastructure, operations and

electricity. A synthesis of different cost estimates gives BECCS a price of €86-172 per tonne of carbon dioxide (tCO₂).⁵ A recent attempt at costing the BECCS project planned by Drax, in the UK, pointed to the need for a public financial support of more than £30 billion for just this one plant.

As the cost of biomass feedstocks rise, so would the cost of BECCS. In comparison, forest protection, restoration and natural management are already in operation. Their costs depend on the price of land and other elements, but estimates range from <8.5-85 €/tCO₂. Technical barriers include the security of carbon dioxide pipelines and storage sites, as leaked highly concentrated carbon dioxide is a lethal risk to the public, ecosystems and the climate, as a recent US accident showed. Injecting compressed carbon dioxide into geological formations can also trigger small earthquakes, themselves possibly causing leakage from the CCS site. As with nuclear waste, storage would need to be permanent, which has significant cost implications. Thus, public concern may form a significant barrier to large scale use of CCS, even more so considering that at least part of the storage costs would be billed to the taxpayer.



⁵ Equalling 100-200 US\$ per tCO₂.

3 – BECCS would require a huge amount of land and push up the price of food

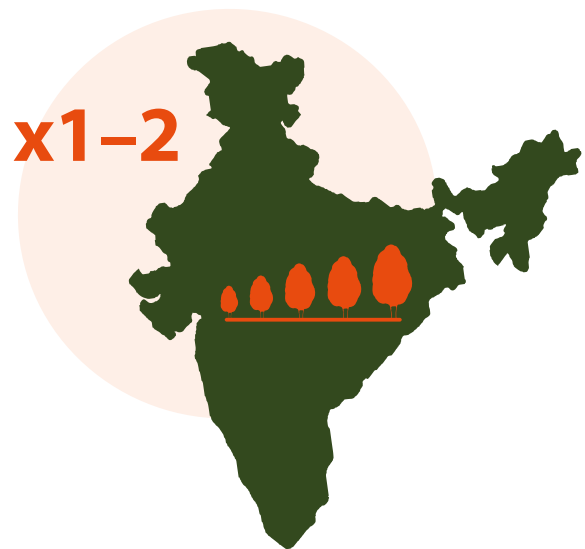
As the human population increases, more land is needed for food. But agriculture is already pushing humans beyond several ecological planetary boundaries. Where will the additional biomass come from? Studies compiled by the Intergovernmental Panel on Climate Change (IPCC) show that the rising price of bioenergy increases pressure on land and the price of agricultural commodities, including food. Scenarios for staying below 1.5 degrees include options for devoting less than 10 million hectares (Mha) to bioenergy, (the size of South Korea) to more than 1000 Mha (the size of Canada).

Growing dedicated crops for BECCS would require 0.1-0.4 hectares of land per hypothetical tonne of carbon removed. The amount of land needed differs depending on the climate scenario, but one example which would give us a 50 per cent chance of keeping global warming below two degrees would require the growing of biomass on a land area 1-2 times the size of India (380–700 million hectares).⁶ This would correspond to converting 25–46 per cent of global arable land and permanent crops to biomass. The amount of land needed rises dramatically if the aim is to limit warming to 1.5 degrees. There are also huge differences when irrigated bioenergy production is excluded, pointing to the fact that there would be a trade-off between water and land requirements if bioenergy is implemented at a large scale.⁷

Such huge land-use change could also cause serious deterioration of soil, making it harder to grow food, and having dramatic impacts on water and biodiversity.

This use of biomass for energy becomes more concerning considering that, in most countries, **solar systems can generate more than 100 times the useable energy per hectare than bioenergy is likely to produce in the future, even using optimistic assumptions.**

TO MEET THE 2 DEGREE AIM AN AREA OF **LAND 1-2 TIMES THE SIZE OF INDIA** WOULD BE NECESSARY FOR BECCS



4 – BECCS would harm biodiversity

Between 1970 and 2012, vertebrate biodiversity declined by 58 per cent, mainly due to the rising human population and intensification of land use.⁸ Increasing demand for land for BECCS would therefore be an additional threat to biodiversity. The areas considered to have good potential for dedicated bioenergy crops overlap with protected areas, especially in central

Europe, the Mediterranean, the US, Central America, South-East Asia and Central Africa.

Biomass that comes from harvesting existing forests harms biodiversity, and this is even worse if the forest is converted to a monoculture plantation. A synthesis study on the impacts of different carbon removal technologies concluded that BECCS would almost certainly reduce biodiversity if implemented

⁶ This is expected to sequester 12 billion tonnes of carbon dioxide annually.

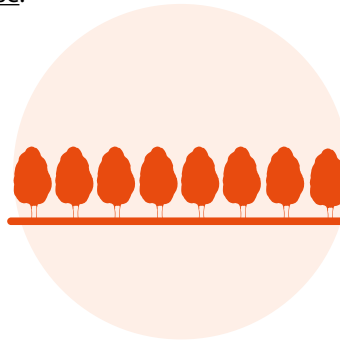
⁷ Another study by Yamagata et al 2017 came up with similar results.

⁸ This is based on the Living Planet Index that measures average change in population abundance over time.

at scale. Large scale BECCS would reduce as many terrestrial species as a 2.8 degrees temperature rise.

The IPCC's views on bioenergy are contradictory, as they recognise the environmental impact of scaling-up bioenergy use, yet they include unsustainable levels in their 1.5 degrees scenarios. There is agreement among scientists that bioenergy should be limited to under 100 exajoules (EJ)/year of bioenergy in 2050 and that deployment at this or higher levels would put significant pressure on food prices and the ability to preserve biodiversity.⁹ Despite this fact, the average amount of bioenergy used in 1.5 degrees scenarios is over 150EJ per year in 2050.¹⁰ This highlights the weaknesses of modelling scenarios that prioritise energy decarbonisation over other environmental impacts

MONOCULTURE



DIVERSE ECOSYSTEM



The Convention on Biological Diversity adopted a moratorium in 2010 on “any technologies that increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity”.

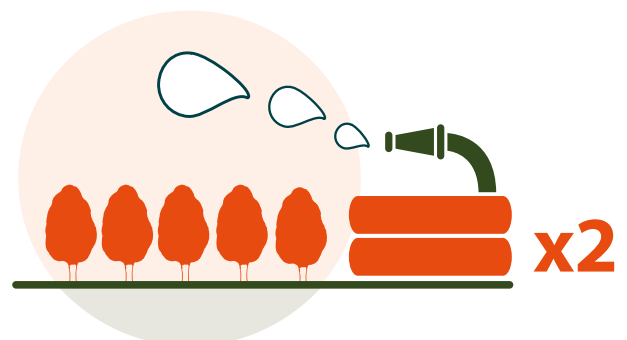
5 – BECCS would take a huge amount of water and threaten more planetary boundaries

When climate modellers talk about ‘additional biomass’ requirements, it is important to consider the large amounts of water it would require. As well as increasing the price of land, biomass demand is expected to increase the price of water by the end of the century, especially in Asia Pacific (by 330 per cent) and Latin America (by 460 per cent). Irrigation is the leading cause to groundwater depletion globally. Already nearly half of the world's population live in areas with water scarcity and this is expected to increase to five billion people by 2050. It is estimated that to produce enough biomass for BECCS to meet the two degrees aim would

require more than doubling the amount of water currently used to irrigate food production.

As well as pushing us beyond the limits of our freshwater use, BECCS is likely to push us beyond other planetary boundaries.¹¹ Researchers have calculated that if regional environmental limits are adopted as precautionary measures the potential for negative emissions from bioenergy plantations is marginal – removing less than 0.1 billion tonnes of carbon per year – a tiny amount of the between 0.6 and 4.1 billion tonnes that is expected to be needed per year by 2050.

DEPLOYMENT OF BECCS TO MEET THE 2 DEGREE AIM WOULD REQUIRE MORE THAN DOUBLE THE AMOUNT OF WATER CURRENTLY USED FOR IRRIGATION IN FOOD PRODUCTION.



⁹IPCC 1.5° Report, Chapter 4, section 4.3.1.2

¹⁰IPCC 1.5° Report, Chapter 2, Table 2.6

¹¹The concept of planetary boundaries is based on the idea that once human activity has passed certain thresholds there is a risk of irreversible and abrupt environmental change. Other planetary boundaries that would be passed include land-system change, biosphere integrity and biogeochemical flows.

6 – BECCS is a barrier to the energy transition

There are already many ways we could reduce fossil fuel emissions globally, such as reducing unnecessary use, improving efficiency, and increasing solar and wind. But instead of delivering on those solutions, the fossil fuel industry is keen to tout BECCS as a fossil fuel-free source of energy, while expecting governments to pay (directly or via incentives) for the actual development costs.

BECCS also encourages continued fossil fuel use in several concrete ways, particularly when it comes to coal and oil.

For example, instead of being decommissioned, many coal power plants are being converted to allow the co-firing of biomass and coal. BECCS power stations that allow for co-firing of biomass with coal would be no different. Co-firing is envisaged as the way to make BECCS facilities economically and technically more feasible. Demonstration projects in the UK and Norway are already testing the CCS of emissions from co-firing biomass with coal.

Even more worrying is the prospect of using the carbon dioxide captured from BECCS plants to extract oil from depleted oilfields through a technique known as enhanced oil recovery (EOR). It

involves pumping gas at high pressure underground to drive oil to the surface and currently allows a further 5 -15 per cent of oil in some reservoirs to be exploited.

Carbon dioxide captured from the current generation of CCS applications (mostly fitted to coal power stations and high emission industrial plants) is already being used on a considerable scale for EOR, partly because CCS is an expensive technology and selling the captured carbon dioxide to oil companies to help them extract more oil is a way of financing the investment. For example, a recently completed largescale retrofit application of CCS to a power plant at Petra Nova in Texas is expected to pay for itself in less than 10 years as a result of carbon dioxide being piped for EOR.

Another concern is the possibility of carbon dioxide leakage, which undermines the climate value of sequestering it in the first place. The US oil industry estimates that about 30 per cent of carbon dioxide piped to an EOR site is directly emitted back into the atmosphere. If old oil fields are not capped properly, carbon dioxide held underground may also find a way out.

DECATUR PROJECT IS NOT CARBON NEUTRAL

The first and only industrial scale BECCS project started operations in 2017 at Decatur in the US state of Illinois. It does not claim to be carbon neutral, let alone a producer of negative emissions. Only 16.5 per cent of the carbon dioxide is captured. The project, run by the US federal Department of Energy and the agribusiness giant Archer Daniels Midland (ADM), involves capturing and burying up to 1.1 million tonnes of carbon dioxide a year emitted as a by-product of fermenting corn into ethanol. Carbon dioxide, which would otherwise have entered the atmosphere, is converted into a “supercritical” fluid and injected into layers of sandstone below the plant, two kilometres underground, for long term storage. The ethanol plant is located within a massive multi-purpose corn processing complex powered by coal. US\$208 million has been invested in the Decatur project with most of the funding (US\$141 million) coming from the US Department of Energy. Carbon storage requires a particular geology: porous rocks, such as sandstone, that are capped by an impermeable layer. According to ADM, the Mt. Simon Sandstone which lies underneath the Decatur plant has the potential to securely store “billions of tonnes of carbon dioxide”. However, it has been suggested that some of the carbon dioxide captured could be used for enhanced oil recovery in South Illinois, perpetuating the use of fossil fuels instead of mitigating it. While the Decatur project is the world’s biggest use of BECCS, the 1.1 million tonnes a year sequestration target is a pinprick in the context of industrial emissions. A single large sized (500 MW) coal-fired power station typically emits three million tonnes of carbon dioxide every year. In addition, the US Department of Energy found that corn-based ethanol in the US is likely at least 24 per cent more carbon-intensive than gasoline. This suggests that land-use change emissions for the BECCS plant are being seriously underestimated. The biofuel inputs of choice for future BECCS projects are more likely to be biomass from trees or high yield grasses than corn.

WHAT ALTERNATIVES DO WE HAVE?

As we have seen, BECCS is unworkable at scale and even in a best-case scenario might not achieve significant negative emissions. It would also have extremely costly financial, environmental and social impacts which go against the [Sustainable Development Goals](#) for zero hunger, clean water, affordable and clean energy, responsible consumption and production, life on land, and climate action.

So what could work? First and foremost, reducing demand for energy by transforming our [houses, power and transport systems](#) and increasing energy efficiency. Secondly, protecting and [restoring natural forests](#), which would benefit biodiversity, help replenish the water cycle and bring climate and social benefits. Forests already store large quantities of carbon and they have been sequestering carbon dioxide for hundreds of millions of years. If protected and managed with the full inclusion of the people that live in and depend upon them, they can help us achieve the targets of Paris Agreement and the Sustainable Development Goals.

But first we must reject a heavy reliance on negative emissions and rapidly reduce emissions from fossil fuels to zero, stop destroying ecosystems, and reduce the overconsumption of natural resources.

RECOMMENDATIONS

Policymakers must :

- Defend climate policies that limit warming to 1.5 degrees
- Not include large scale BECCS (or other unproven) technology in climate policies and scenarios, nor incentivise or financially support the technology
- Reduce emissions as fast as possible in all sectors so as to minimise the need for negative emissions
- Protect and restore natural ecosystems so that they can play their role of carbon sink, in ways that respect the people who depend on the land
- Restrict public support for the use of biomass for energy production to biomass sources whose payback time is less than a decade (essentially, wood processing residues)

