Six problems with BECCS

The climate emergency is on the verge of becoming a climate crisis. Years of inaction have meant that climate scientists are no longer just discussing the need to reduce emissions, they are also talking about having to remove carbon dioxide from the atmosphere. Known as negative emissions, carbon dioxide removals are now at the centre of the climate conversation.

Governments are responding by looking for technological fixes, and one of the most often discussed is Bioenergy with Carbon Capture and Storage (BECCS). But the belief that BECCS would remove emissions is based on the faulty assumption that bioenergy is carbon neutral. This is not the case. BECCS would also have massive social, environmental and economic costs. It offers the false promise of a get-out clause and must not be allowed to distract from the urgent need to stop burning fossil fuels and to protect and restore forests, soils and other ecosystems.

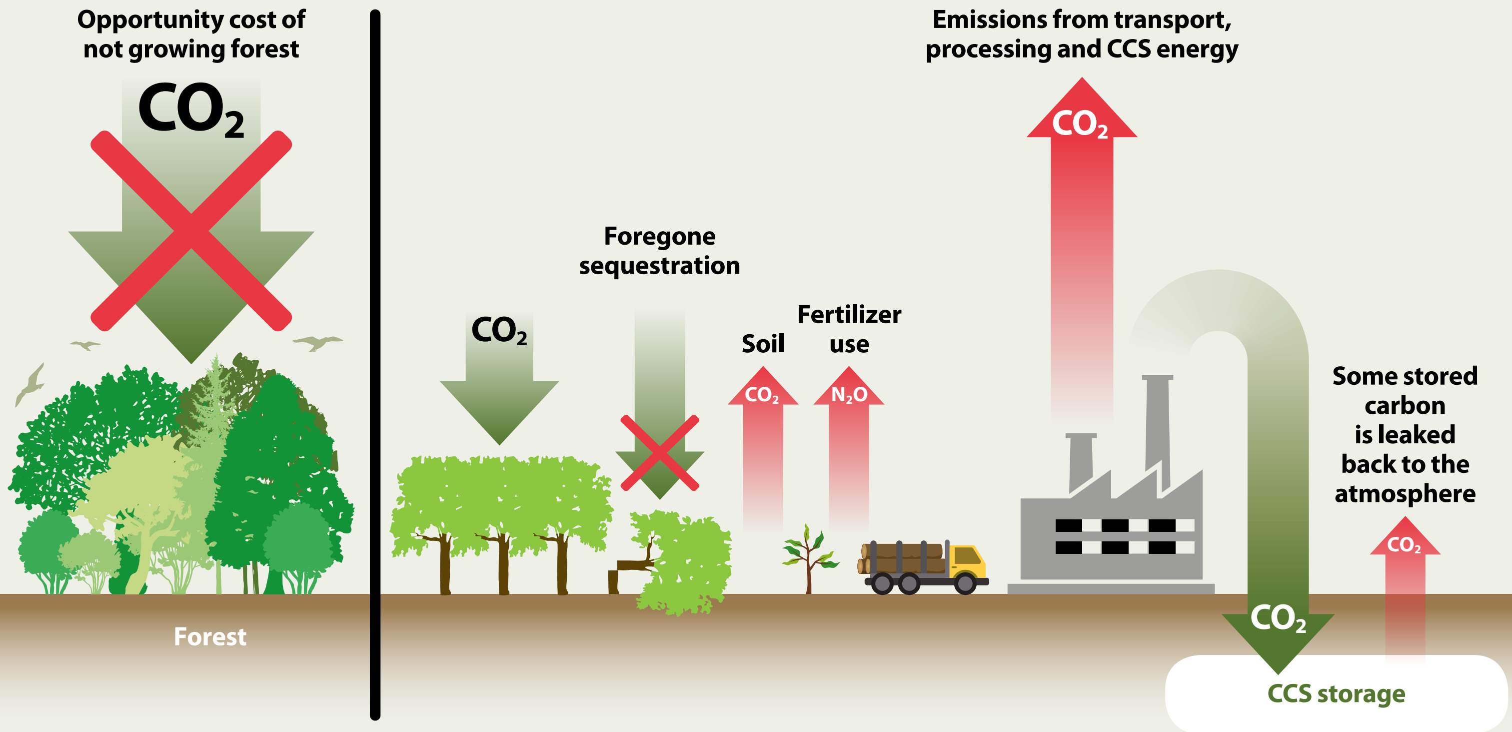
Why climate models rely on negative emissions

The 2015 Paris agreement on climate change has been signed by almost all the world's countries. Its central aim is "to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius."

To achieve the 1.5 degrees aim, we need to keep the concentration of greenhouse gases in the atmosphere below 430 parts of carbon dioxide per million (ppm). This is a daunting challenge given that they are currently at 403 ppm, up from 277 ppm in 1750, and are continuing to rise.

Each year human activity pumps greenhouse gas emissions into the atmosphere equivalent to 37 billion tonnes of

Would BECCS deliver negative emissions?



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

Against this grim background, researchers have modelled hundreds of scenarios for how to stabilise the climate, taking both socio-economic factors and climate science into account. Most of these scenarios say it is too late to keep global warming below two degrees let alone 1.5 degrees simply by cutting emissions.

Instead, they assume that future technologies will be able to remove more carbon dioxide from the atmosphere than future economies will emit.

Taking carbon dioxide out of the atmosphere is known as carbon dioxide removals or "negative emissions".

Most scenarios for keeping to 1.5 degrees predict that we will overshoot carbon dioxide emissions and then subsequently remove between 450 and 1000 billion tonnes of carbon dioxide by 2100. There are presently no negative emissions technologies that work at scale, and those being suggested have significant risks of damaging environmental, social and economic impacts. It is therefore important to rely on negative emissions technologies as little as possible and prioritise full and fast decarbonisation.

One suggested technology to deliver negative emissions BECCS has attracted the bulk of the attention. Most of the Intergovernmental Panel on Climate Change (IPCC) scenarios for mitigating climate change assume a major role for BECCS. Even those scenarios that rely on large scale electrification, energy efficiency, limiting non-carbon dioxide emissions and large-scale lifestyle changes often have a limited role for BECCS.

Photo: Fred Pearce

Burning whole trees for energy is not carbon neutral. Power plant in Bardejov, Slovakia.

What is BECCS?

BECCS is a geo-engineering technique to remove carbon dioxide from the atmosphere. Plants such as trees or agricultural crops naturally remove carbon dioxide, they are then burnt to produce energy and the emissions are captured and stored in geological formations underground.

The theory is this can be considered negative emissions if the plant growth is additional to existing or foreseen plant growth as the carbon dioxide removed is also therefore additional.[1] As the carbon dioxide from biomass combustion is not released, but captured and stored, the extra plant growth removes emissions already in the atmosphere. It is touted as a win-win which provides an alternative for fossil fuel energy while removing carbon dioxide from the atmosphere. In practice there are no operational BECCS facilities claiming to produce substantial negative emissions anywhere in the world, and many scientists have highlighted feasibility constraints that would make it unlikely to ever work, at least not on the scale foreseen.

This briefing note is based on a literature review of studies on BECCS. It outlines six reasons why policy makers planning decarbonization pathways for 2050 or beyond must not rely on BECCS to achieve negative emissions.

1. BECCS may not deliver large scale carbon dioxide removals

BECCS is proposed as a solution based on the assumption that bioenergy is carbon neutral.[2] This assumption is flawed, notably because of emissions from land use and forestry.[3]

Even in a best-case scenario where bioenergy was made 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 biomass growth, transport, refining, capturing and storing. These could considerably reduce the positive impact of the capture and storage of the combustion emissions.

There are four main types of emissions to consider:

A. Harvesting a forest reduces 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. 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. In addition, while a forest left standing continues to remove carbon dioxide, the moment it is cut down sequestration stops. The lost sequestration of a harvested forest is known as foregone sequestration.

Increasing demand for biomass can lead to intensification of forest management and higher harvesting levels, which can reduce future growth and hence the ability of forests to sequester carbon dioxide. If forests are continually harvested more intensively due to bioenergy, they will never be able to recover the loss in carbon stock or the emissions released during combustion.

If bioenergy is to reduce emissions, biomass growth must be additional to what would have happened without the bioenergy use.[4] The potential for additional biomass sources, such as biomass grown on degraded land or (industrial) residues and wastes, is extremely limited.

B. Land-use change such as forests being converted to agricultural land is one of the largest 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 could drive deforestation.[5]

   The rapid growth of wood for energy could also increase indirect emissions from material displacement. This is when competition for wood leads to the use of more carbon intensive materials, such as concrete or metals.

C. There are also 'opportunity costs' to consider. Without bioenergy demand and the associated production of bioenergy crops, there could be larger climate benefits from alternative land and biomass uses. Examples are the restoration of natural forests and the use of biomass for 'long lived products', such as durable wood construction.

D. Finally, additional emissions from the production of biomass, the supply chain and Carbon Capture and Storage (CCS) can negate the potential climate benefits of BECCS. The growth of biomass can lead to a large increase in fertilizer use. This is particularly problematic as nitrous oxide (N_2O) (which is released in fertilizer creation, storage and use) has a global warming potential up to 300 times higher than carbon dioxide. Scientists trying to quantify the global warming effect of increased use of N_2O 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 (the additional fuel required when CCS is applied is up to 31 per cent for coal fired installations), which will increase the requirement for biomass or other energy sources. There is also a risk of carbon dioxide leaks from carbon storage sites.

   The supply chain emissions can be significant. In the case of dedicated bioenergy crops, emissions from transport, processing and using carbon capture and storage technology already represents 64 per cent of all carbon stored in the first place. For one tonne of carbon dioxide sequestered and stored underground, emissions from the supply chain would amount to 1.11 tonnes of carbon dioxide.

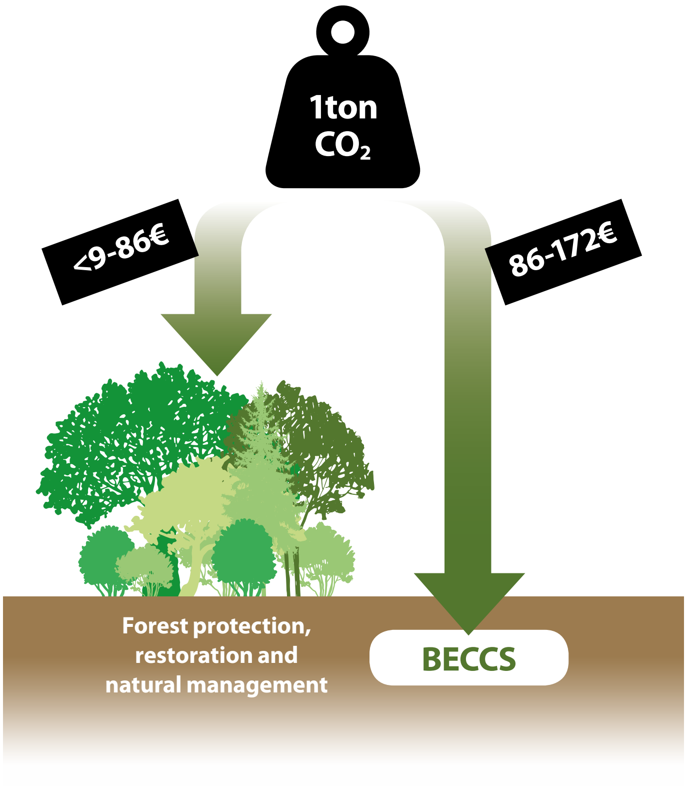
In conclusion, the assumption that BECCS at scale can provide a significant amount of additional carbon dioxide removals from the atmosphere, is flawed. Even more disturbingly, a report by the European Academies science Advisory Council recognises the risk of BECCS worsening climate change and recommends the climate impacts of BECCS to be assessed case by case.

2. BECCS has technical barriers and is expensive

Most of the 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 it faces significant questions about feasibility, scale and cost.

Costs for BECCS are difficult to estimate as they depend on the price of biomass feedstock, CCS components, infrastructure, operations and the price of electricity. A synthesis of different cost estimates gives BECCS a price of 86-172 € per tonne of carbon dioxide (tCO_2).[6] As a comparison, during the first half of 2018, the carbon price in the EU Emissions Trading System was 8-17€/tCO_2.[7]

As the cost of biomass feedstocks rise, so would the cost of BECCS. Even in modelled scenarios which include a high level of biomass availability (100 exajoules per year),[8] costs would quickly increase to a level where negative



emission technologies such as direct air capture (DAC) become financially competitive. In comparison to these little tested options, 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 €/tCO_2.

Technical barriers include the safe storage of carbon dioxide. The security of these sites is a great concern to public safety, ecosystems and the climate as leaked highly concentrated carbon dioxide would have very damaging impacts. 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 at least part of the costs would be billed to the taxpayer for thousands of years to come.

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

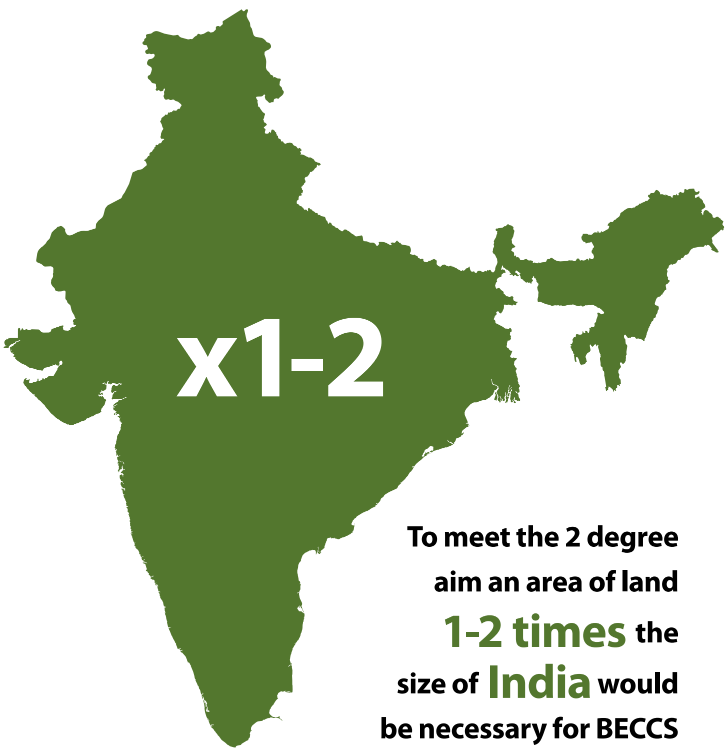
As the human population increases, more land is needed for food, animal feed and other biomass uses. This is made even more problematic by the increase in meat-eating, as rearing animals takes more land than growing pulses. In addition, climate change and land degradation are reducing the extent of areas suitable for biomass production.

Climate modellers looking at scenarios for staying below 1.5 degree 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). A conservative yet highly unlikely estimate would be that 100 EJ/year of bioenergy could be provided in 2050. This would take the equivalent of 31 per cent of existing cropland (500Mha).[9] These estimates do not include an assessment on the social, climate or other environmental impacts of this amount of biomass and land being used.

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 meeting the aim 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).[10] This would correspond to globally converting 25–46 per cent of arable land and permanent crops to biomass. The land requirement rises dramatically if the aim is to limit warming to 1.5 degrees, or if irrigated bioenergy production was excluded, so there would be a trade-off between water and land requirements if bioenergy is implemented at a large scale.[11]

Such huge land-use change could also cause serious deterioration of soil accompanied with degradation of vegetation productivity. This would have further dramatic impacts on food, water and biodiversity.

Studies show that as a result of decreasing land availability BECCS would likely increase food prices, but all such scenarios



Large scale BECCS will almost certainly accelerate biodiversity loss

remain highly speculative because the impact of climate change on yields is still unclear. BECCS would put pressure on limited natural resources, and thus increase conflict for land, biomass and water.

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.[12] Increasing demand for land for BECCS is therefore 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 United States of America, Central America, South-East Asia and Central Africa.

When biomass comes from harvesting existing forests, biodiversity is harmed during the harvest and this is even worse if the forest is converted to a monoculture plantation. In a synthesis study on the impacts of different carbon removal technologies, the conclusion was that BECCS would almost certainly reduce biodiversity if implemented at scale. Large scale BECCS would reduce as many terrestrial species as a 2.8°Celsius temperature rise.

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 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.

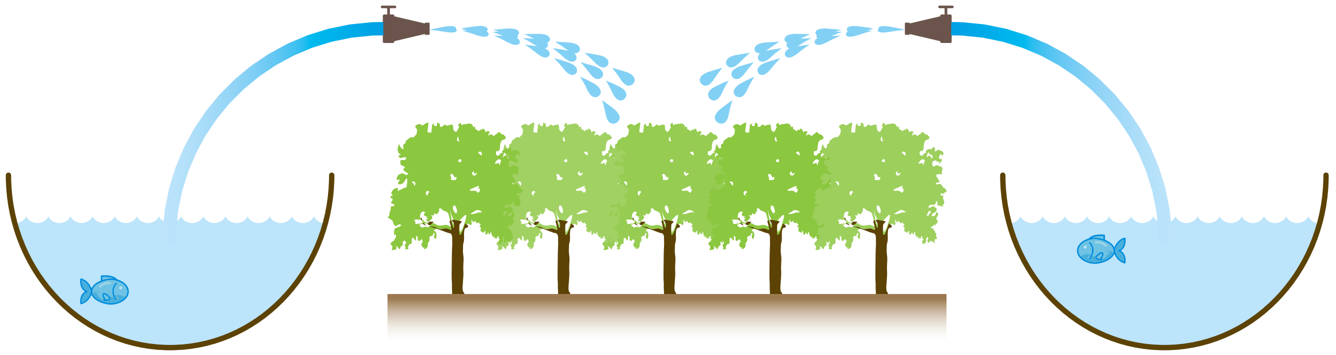
It is estimated that to produce biomass crops for enough BECCS to meet the two degrees aim would require more than a doubling of the amount of water used currently for irrigation globally for food production.

As well as pushing us beyond the limits of our freshwater use, BECCS is likely to push us beyond other planetary boundaries.[13] Researchers have calculated that if regional environmental limits are adopted as precautionary measures the potential for negative emissions from bioenergy plantations is marginal – less than 0.1 billion tonnes of carbon out of the atmosphere per year – a tiny amount given that the amount needed is expected to be between 0.6 and 4.1 billion tonnes carbon per year in 2050.

6. BECCS is a barrier to energy transition

BECCS is presented as a fossil fuel-free source of energy, but there are various ways in which it encourages continued use of coal and oil in particular.

Bioenergy without CCS is already offering a life-line to coal, as 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 with coal is envisaged as the way to make BECCS facilities



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

economically and technically more feasible. Demonstration projects in the UK and Norway are already testing the CCS of 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 oil fields 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, which could in effect double the potential of these oil fields.

Photo: David Wright (CC by 2.0)

Miscanthus is harvested for energy in the UK.

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. Another problem is that old oil fields are sometimes not capped properly which means carbon dioxide held underground may find a way out.

Finally, reliance on negative emissions and especially BECCS can come at the cost of measures to reduce emissions, like energy efficiency, solar and wind energy. The promise of BECCS also deters us from looking critically at our levels of energy and resource consumption.

What alternatives do we have?

As we have seen, BECCS is unworkable at scale and even in a best-case scenario it is unlikely to achieve significant carbon dioxide removals. It would also be extremely costly both financially and in terms of its environmental and social impacts. The trade-offs also fly against the Sustainable Development Goals for zero hunger, clean water, affordable and clean energy, responsible consumption and production, life on land and climate action.

Another often raised proposal to remove carbon dioxide is large-scale afforestation, but this also requires huge amounts of land, fertilizer and water. The impacts on the climate and biodiversity are context specific, but bad practices such as creating monoculture plantations on lands not suitable for forests that are then harvested for short-lived products, would make afforestation no more environmentally sustainable than BECCS.

So what could work?

The answer is surprisingly simple. Protecting and restoring natural forests would benefit biodiversity and also bring climate and social benefits.

Unlike BECCS, restoring natural forests' climate benefits are tried and tested. Forests already store large quantities of carbon and they have been sequestering carbon 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:

- Agree climate policy that limits warming to 1.5 degrees
- Reduce emissions as fast as possible in all sectors so as not to rely on negative emissions
- Protect and restore natural ecosystems in ways that respect the people who depend on the land
- Restrict public subsidies for the use of biomass for energy production
- Not include large scale BECCS (or other unproven) technology in climate models nor subsidise the technology

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 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.

The corn to ethanol fermenting process produces an almost pure stream of carbon dioxide as waste. This makes capturing and processing the emissions cheaper and easier than other forms of bioenergy. 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.

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.

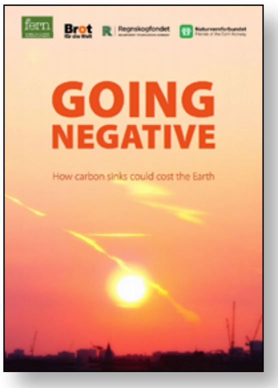
The biofuel inputs of choice for future BECCS projects are more likely to be biomass from trees or high yield grasses than corn. Carbon dioxide emissions from these fuels are harder, more expensive and more energy intensive to capture, which makes the process less efficient than capturing emissions from ethanol fermenting.

Endnotes

1. Additional carbon dioxide removals mean an increase in the amount of carbon stored in ecosystems annually.
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 briefing on the energy use of woody biomass.
4. This is the principle of additionality, which means that to reduce emissions, the feedstock must not already be performing a function as part of the terrestrial carbon cycle.
5. Land use change can also lead to climate 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.
6. Equalling 100-200 US$ per tonne of carbon dioxide (tCO2).
7. Carbon price is the amount that must be paid for the right to emit one tonne of carbon dioxide into the atmosphere.
8. This amount of availability is unlikely considering that in 2000 the total amount of energy in all the crops, plant residues, and wood harvested by people for all applications (e.g., food, construction, paper) and in all the biomass grazed by livestock around the world was roughly 225 exajoules (EJ). See Searchinger and Heimlich, 2015.
9. This calculation draws on information from two sources: National Research Council (2015) and FAO land data 2010.
10. This is expected to sequester 12 billion tonnes of carbon dioxide annually.
11. Also, another study by Yamagata et al 2017 arrived to similar results.
12. This is based on the Living Planet Index that measures average change in population abundance over time.
13. The 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.

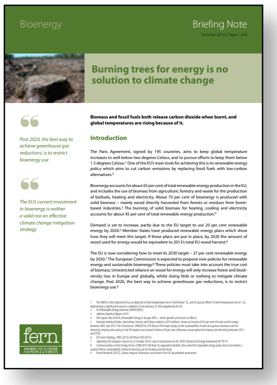
Underlined text shows hyperlinked citations. To see the fully hyperlinked version visit: www.fern.org/beccsbriefing

Further reading



Risks of negative emissions are outlined in Fern's report Going Negative.

Fern's report Protect and Restore shows how its own forests can help the EU tackle climate change.



Fern's briefing Burning trees for energy is no solution to climate change.

MAKING THE EU WORK FOR PEOPLE & FORESTS

Fern office UK
1C Fosseway Business Centre, Stratford Road, Moreton in Marsh, GL56 9NQ, UK

Fern office Brussels
Rue d'Edimbourg, 26, 1050 Brussels, Belgium

www.fern.org

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Willow Coppice Plantation, United Kingdom