IPCC Working Group III report: Bioenergy with carbon capture and storage (BECCS)

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This briefing summarises the main insights in the IPCC Working Group III report on Bioenergy with Carbon Capture and Storage (BECCS). The focus is on potential and feasibility of BECCS in climate mitigation, rather than the broader bioenergy sustainability topics.

Key points

- BECCS can help to mitigate climate change, but it is not a silver bullet solution.
- BECCS could have positive impacts, but there are many uncertainties, particularly when considering environmental and social-economic issues. **BECCS is one of the heavily relied on CDR methods in climate models**, however, an area twice the size of Egypt could be needed to deploy BECCS in 2100, in pathways limiting warming to 1.5°C. Very large scale deployment would threaten food production and security, and damage ecosystems.
- **Delaying mitigation would put a lot of pressure on CDR, requiring large-scale deployment of BECCS to reduce the temperature overshoot, causing substantial land use change**. Earlier mitigation would be essential to reduce the pressure on land and its associated impacts.

Bioenergy and BECCS: The basics

Bioenergy refers to energy products, such as fuels or electricity, that come from organic sources (e.g. waste, wood or crops).[1] It is often promoted as a 'climate neutral' solution, as in theory these organic sources only release the carbon dioxide (CO_2) they had already absorbed when burnt. But, this characterisation depends on many assumptions, such as the type of feedstock used. Bioenergy could also help deliver other mitigation options, such as carbon sequestration from integrating trees into crop systems (e.g. agroforestry) that provide the feedstock for bioenergy.

When combined with carbon capture and storage (CCS), bioenergy is seen as a carbon dioxide removal (CDR) option. This is because the CO_2 emitted is then captured and stored in geological, terrestrial, or ocean reservoirs, or in manufactured products. BECCS may also reduce net GHG emissions by displacing the use of fossil fuels with renewable biomass in the production of heat, electricity and fuels.[2]

Benefits and risks of BECCS

The IPCC is careful when talking about BECCS. It stresses that it is a crucial CDR option, but its potential depends on many social and environmental considerations (e.g. the choice of feedstock, management practice, and deployment strategy and scale). The report does not assess all these options in-depth.

BECCS could have positive impacts, the IPCC says. But only if some strategies are followed to enhance its benefits, such as adopting management practices that protect carbon stocks.[3] The use of feedstocks that do not need land (e.g. municipal organic waste or harvest residues) could also provide bioenergy at a significant, but limited, scale.[4] These can reduce negative impacts associated with land use. Selecting crops that can produce both protein feed and biofuels could also reduce pressure to convert lands.[5] Some technologies could generate co-benefits, such as anaerobic digestion of organic waste and wastewater, and those that convert indigestible biomass like algae into food and feed.[6]

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[1] Chapter 7, p. 77
[2] Chapter 7, p. 77, Chapter 6. p.93
[3] Chapter 7, p.81
[4] Chapter 7, p.78, Chapter 6, p. 40
[5] Chapter 12, p. 103
[6] Chapter 12, p. 103

If BECCS is poorly planned, however, it can “have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure”. [7] Major scale-up of bioenergy production, for example, will need more than wastes/residues and cultivation on marginal lands. This will require more land and water, harming biodiversity and, potentially harming food security. Thus, **“bioenergy systems may fail to deliver near-zero emissions depending on operating conditions and regional contexts”**.[8]

The IPCC says **“it is therefore not possible to precisely determine the scale of bioenergy and BECCS deployment at which negative impacts outweigh benefits”.**[9] “As a result, bioenergy carbon neutrality is debated... and the lifecycle emissions of BECCS remain uncertain and will depend on how effectively bioenergy conversion processes are optimised”.[10] The future of BECCS also depends on the roll-out of CCS technologies, it adds.[11]

Mitigation potential of BECCS

Bioenergy and BECCS can represent an important share of the total mitigation potential, the IPCC says, but conclusions on how big a share vary due to the large diversity of studies and their assumptions about where and how BECCS is deployed (e.g. the associated land use).[12,13] The IPCC concludes that:

- The range of recent estimates for the technical bioenergy potential when constrained by food security and environmental considerations is 5–50EJ/yr by 2050 for bioenergy that uses residues for feedstocks, and 50–250 EJ/yr by 2050 for a dedicated biomass production system.[14] For context, 250 EJ/yr is equivalent to 20%–30% of global primary energy demand.
- The global technical CDR potential for BECCS by 2050 (i.e. considering only the technical capture of CO_2 and storage underground) is estimated at 0.5-11.3 billion tonnes of CO_2 a year ($GtCO_2$ a year).[15,16] But, when considering cost effectiveness (less than USD100 per tonne of CO2-eq), the potential is reduced to 0.2- 9.9 $GtCO_2$ a year.[17] Currently, only 40 million tonnes of CO_2 is captured a year via CCS, meaning we would need nearly a 150-fold increase in CCS capacity for this amount of BECCS. Moreover, most of the captured carbon today is used for enhanced oil recovery (EOR), rather than permanent geological storage. This undermines emissions cuts as emissions from burning recovered oil could more than offset the benefits of capturing the carbon dioxide in the first place, by a factor of up to three.
- **Therefore, the IPCC urges caution about these estimates as they reflect only biophysical and technological conditions**. These estimates can be reduced when factoring in economic, environmental, socio cultural and institutional constraints. For example, the mitigation effect of BECCS could be reduced if models start to include the diminishing ability of land to remove CO_2 from the atmosphere due to future climate change.

The role of BECCS in mitigation pathways

There has been “fervent debate” on the use of bioenergy with CCS in mitigation scenarios.[18] Reliance on it has been criticised for causing biodiversity loss, undermining food security, creating uncertain storage potential, excessive water use as well as creating the potential for temperature overshoot.[19] The overall land for bioenergy production is modelled to take place in tropical regions, where croplands for bioenergy displace land for food production (cropland and pasture) and other natural land. For example, in the 1.5°C mitigation pathway in Asia, bioenergy and forested areas together increase by about 2.1 million

[7] SPM, p.47
[8] Chapter 6, p.42
[9] Chapter 7, p.77-78
[10] Chapter 6, p.42
[11] Chapter 7, p.96 and chapter 7 , p. 6
[12] Chapter 7, p.7
[13] Chapter 7, p.79
[14] Chapter 7, p.6
[15] Excluding economic costs and/or sustainability concerns
[16] Chapter 12, p. 55.”These potentials do not include avoided emissions resulting from the use of heat, electricity and/or fuels provided by the BECCS system”.
[17] Chapter, 7, p.45
[18] Chapter 3.2.2
[19] Chapter 3, box 3.4

square kilometres – an area the size of Saudi Arabia – between 2020 and 2100, mostly at the cost of cropland and pasture.[20] BECCS is also typically associated with delayed emissions reduction in the near-term.[21]

Among CDR methods, BECCS is one the most common in climate models (i.e. integrated assessment models, or IAMs) to limit temperature rise to 2°C or lower.[22] Currently, few models represent other options, such as biochar or soil carbon sequestration. In fact, all illustrative mitigation pathways (IMPs) from the WG3 report primarily BECCS (for comparison with other land CDR options and discussion of BECCS in models, see here).

Across the scenarios reviewed by the IPCC, in those likely to limit warming to 2°C or lower, **the cumulative volumes of BECCS reach 328 (median values) $GtCO_2$ respectively for the 2020-2100 period.** Translated to annual volumes, the IPCC sees BECCS removing about 2.75 $GtCO_2$ a year. [23] To put this into perspective, scientists predict that up to 10 $GtCO_2$ will need to be removed annually to reach global emissions targets by 2050.

Many IAM pathways include large increases in cropland area to supply biomass for bioenergy and BECCS, with 199 (56-482) million hectares in 2100 in pathways limiting warming to 1.5°C with no or limited overshoot.[24] To put this into perspective, 102 million hectares of land - an area the size of Egypt - have been converted to cropland since the start of the 21st century.

Delaying mitigation would increase pressure on land because it would require large-scale deployment of CDR in the second half of the century to reduce temperature overshoot. The main CDR measures are BECCS and afforestation and reforestation because climate models use these measures as proxies for land-based mitigation. This will cause substantial land use change in 2050. Early mitigation reduces the amount of land required for this, though at the cost of larger land use transitions earlier in the century. Earlier action could also reduce climate impacts on agriculture and other land-mitigation options.[25]

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[20] Chapter 7, figure 7.14
[21] Chapter 3, box 3.4
[22] Afforestation and reforestation is also widely used. See here for more info.
[23] Chapter 12, p. 40
[24] Chapter 3, p.6
[25] Chapter 3, p.66