Met Office

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Met Office Hadley Centre Climate Briefing Note

Strategies for limiting warming to 1.5/2°C - the challenges of carbon dioxide removal

This briefing note looks at options and challenges for land-based strategies to limit global warming, based on findings of the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Climate Change and Land (SRCCL) and research from the Met Office Hadley Centre and research partners.

The Paris Climate Agreement aims to limit warming to well below 2°C above pre-industrial levels and make efforts to limit it further to 1.5°C. Large and rapid reductions in global CO_2 emissions are required in order to meet these goals. In addition to this, it's likely we will need to start removing CO_2 from the atmosphere (known as carbon dioxide removal or CDR) in greater quantities than we emit it – a so-called 'negative emissions' scenario.

Do we need carbon dioxide removal to meet the Paris Agreement goals?

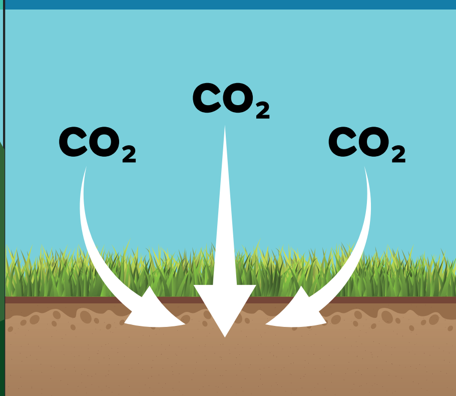
All the potential future pathways that climate scientists have assessed to limit warming to 1.5°C typically require extensive use of land-based carbon dioxide removal, with most including a combination of extensive planting of trees, large-scale bioenergy and, in the majority of cases, use of Bio-Energy Carbon Capture and Storage (see explanations in the box below). Pathways in which warming exceeds 1.5°C require less land-based mitigation, but the impacts of higher temperatures on regional climate and land, including land degradation, desertification, and food insecurity, become more severe. Therefore use of land-based carbon dioxide removal is likely to feature in global efforts to meet the Paris Agreement.

Met Office — Land-based carbon dioxide removal options

Planting trees

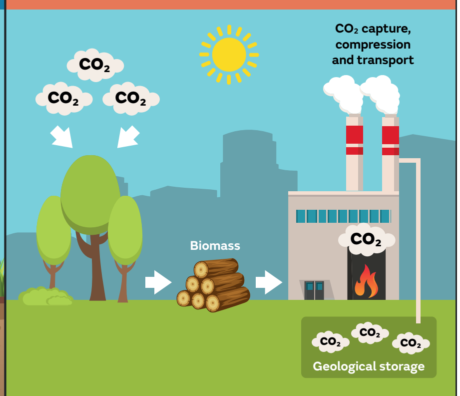
Planting new forests or replanting those that have been cut down.

Soil carbon storage



Soil's ability to store carbon can be increased, such as by better land management or creating charcoal from plants.

Bio-Energy Carbon Capture and Storage (BECCS)



Bioenergy crops are grown, then burned to produce energy. The carbon released as they are burned is captured (using technology) and stored underground.

There are also other options, such as speeding up the process that some types of rock absorb CO_2 or using technology to directly suck CO_2 from the atmosphere. These methods are more speculative and currently unproven at the scale required to be effective.

What action gives us the best chance of meeting the Paris Agreement goals?

Research suggests taking rapid action to reduce greenhouse gas emissions alongside taking measures to adapt to climate change offers the best strategy to limit warming and its associated impacts, as well as reduce losses and generate benefits to society. As some form of carbon dioxide removal will likely be needed, the Met Office and research partners have been investigating the issues around using the land to most efficiently absorb and store carbon. This involves looking not only at the global balance of carbon removal mechanisms, but also what might be most appropriate in a given region.

What challenges are there to land-based carbon dioxide removal?

Biofuels and BECCS (see definition in graphic on previous page) are currently the most preferred options for carbon dioxide removal because they can help achieve negative emissions while also providing a source of fuel. However, research suggests there are limits to the extent to which they can be used. Widespread use at the scale of using several millions of km^2 of land globally could compromise sustainable development with increased risks, and potentially irreversible consequences, for food security, desertification and land degradation. Depending on how much we try to restrict warming and the pathway chosen to meet that goal, bio-energy carbon dioxide removal strategies could require between 0.8 and 6.6 million km^2 (an area twice the size of India) of land. As such, it is important to carefully weigh up the benefits of BECCS with the potential detrimental consequences of biocrop growth on food production, biodiversity, and deforestation.

In many instances, the conversion of land in order to grow bioenergy crops may cause the loss of carbon from soil and vegetation, resulting in the release of carbon into the atmosphere. In some instances, for example in carbon-dense forests, the trees cleared to allow for bioenergy crop planting are more effective at storing carbon than BECCS over the coming decades. If land in the tropics is converted for BECCS use, it could take between 10-100 years for the land to recover its prior ability to store carbon, and so the use of BECCS may not be the best option[1]. Therefore it is important to consider the ability of land to store carbon before it is earmarked for BECCS use.

The balancing act of successful land-based mitigation

A recent study[2] explored how effective BECCS is in reducing CO_2 looking at two potential future pathways: one aimed to restrict warming to 1.5°C using a high mitigation/adaptation approach to reducing atmospheric carbon dioxide and another for 2°C using a medium approach. It found that more ambitious mitigation scenarios to meet a 1.5°C target could actually result in a net loss of carbon storage in land – the opposite effect of that intended. If BECCS involves replacing high-carbon content ecosystems (such as forests) with crops, then planting trees or leaving forests intact could be a more efficient strategy for atmospheric CO_2 removal. This is due to a number of factors, and highlights the need to take a carefully managed approach to BECCS in order for it to be successful.

What further information is needed to make informed choices?

The latest generation of climate models, such as the UKESM1 which has been developed by Met Office and NERC, include Earth system processes which have been previously omitted. They also provide a greater level of detail than earlier models, which could help explore regional effects of carbon dioxide removal strategies in more detail. Analysis of the output of this new generation of models should help advance understanding of the most effective future role of the land surface to achieve the Paris Agreement goals.

[1] Fajardy & Mac Dowell (2017), Can BECCS deliver sustainable and resource efficient negative emissions?
[2] Harper et al (2018), Land-use emissions play a critical role in land-based mitigation for Paris climate targets