Do we need carbon removals?

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Summary

The Paris Agreement sets out a goal to limit global warming to 2°C or less, which requires rapid and substantiative cuts to greenhouse gas emissions (GHGs). Most scenarios for limiting global warming by 2050 require some degree of carbon removals, through engineered solutions, afforestation and land use change, or a combination of them all.

Key Drax take-aways

- There are a range of scenarios and pathways that would allow nations to meet net zero targets. Each scenario has a different emphasis on the changes to industry, energy and human behaviours required to meet net zero.
- There's agreement that, to reach net zero, reducing emissions should be a priority. In addition, it's agreed that some amount of carbon dioxide (CO_2) removal will be needed to reduce net emissions, offset residual emissions and/or to manage overshoot. The magnitude of removals required is dependent on assumptions about the speed at which aggressive emissions reductions can be achieved. The more conservative of these scenarios require CO_2 removals of around 2 Gt per year, with others reaching 4.5 Gt CO_2 or more per year.

Report

The Paris Agreement, signed by 196 countries in 2015, sets an ambition to limit global warming to less than 2°C relative to pre-industrial temperatures. It also aims to establish a strategy to limit warming to no more than 1.5°C. Under this agreement, individual nations set targets for emissions reductions, referred to as Nationally Determined Contributions (NDCs). However, the NDCs presently agreed are insufficient to deliver the reductions required to limit warming to 1.5°C (Rogelj *et al.* 2022).

In 2023, the United Nations Environment Programme (UNEP) Emissions Gap Report concluded that "Failure to bring global GHG emissions in 2030 below the levels implied by current NDCs will make it impossible to limit warming to 1.5°C with no or limited overshoot and strongly increase the challenge of limiting warming to 2°C" (UNEP, 2023).

What's net zero?

The IPCC defines net zero as a balance between the anthropogenic emissions of GHGs to the atmosphere and the anthropogenic removals of GHGs over a specific period. When the focus is emissions of CO_2, this balance may also be referred to as carbon neutrality (IPCC, 2018). Within this concept, anthropogenic removal of GHGs take place through negative emissions (greenhouse gas removal; GGR), and for CO_2 specifically, carbon dioxide removal (CDR).

The IPCC's definition of CDR includes capture and storage as well as the anthropogenic enhancement of natural biological and geochemical sinks. Either way, CDR results in carbon durably stored in geological, marine, or terrestrial reservoirs, or in long-lived products. This definition is agnostic regarding the source and fate of the carbon. This means that carbon released from fossil fuels can be transferred to shorter-lived biological reservoirs, for instance through reforestation of degraded land.

In contrast, Myles Allen and colleagues (2022) argue for a concept they call durable or geological net zero, which calls for a "like-for-like balancing of anthropogenic greenhouse gas sources and sinks in terms of both origin (biogenic versus geological) and gas lifetime." Under this model,

fossil CO_2 emissions must be compensated through the geological storage of CO_2, (i.e. not compensated by nature-based solutions). It would also mean that, for example, CO_2 emissions could not be offset by reductions in methane emissions, due to the different atmospheric lifetimes and global warming potentials of the gases.

This paradigm is based on the differentiation between carbon in organisms (biogenic carbon) and geologic sources of carbon. The former cycles between the atmosphere and terrestrial ecosystems relatively quickly, while the latter will take millions of years to re-enter geologic reservoirs without human intervention. Allen *et al.* (2022) also argue for a primary focus on achieving net zero emissions on long-lived climate forcers such as CO_2 and nitrous oxide (N_2O), with substantial decreases in methane emissions.

Scenarios to limit warming to 2°C or lower

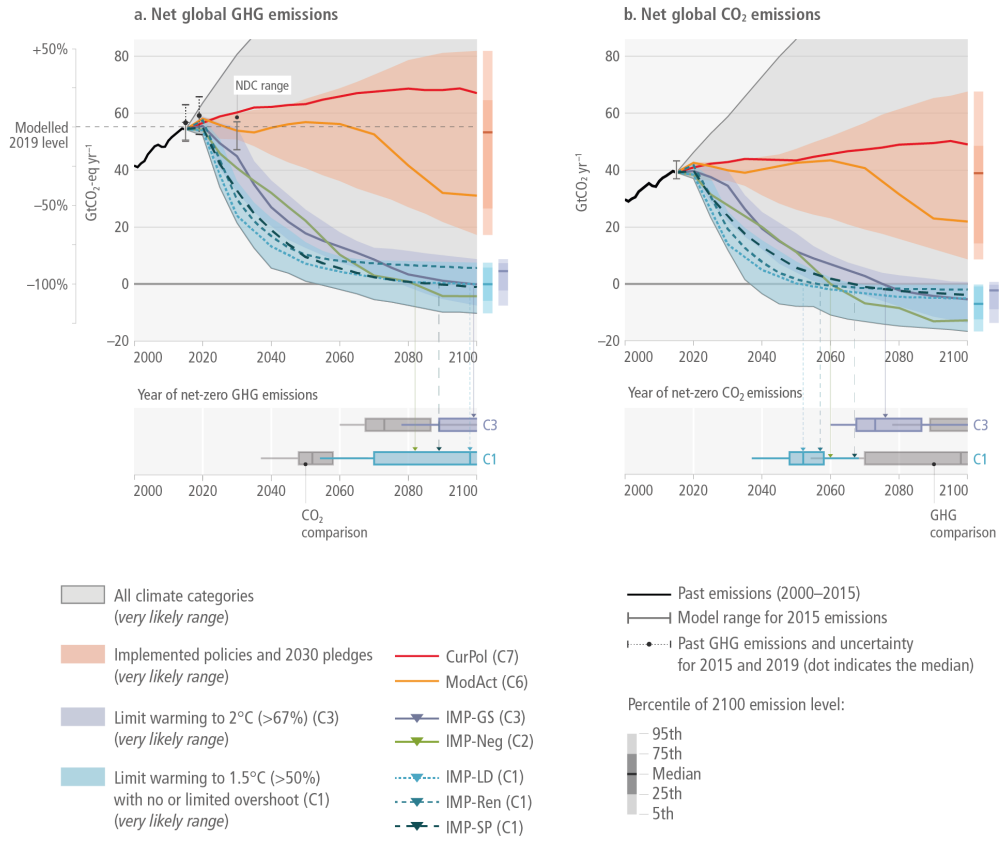
In the IPCC's Sixth Assessment Report (AR6), Working Group III analysed 1,202 emissions pathways to understand how choices around decarbonisation speed and priorities could impact our ability to limit warming to 1.5 or 2°C. The pathways that saw warming limited to 1.5°C with little to no overshoot (temperature increase above the target) require a 50% reduction of emissions by the 2030s, reaching net zero emissions in the 2050s. For scenarios in which warming was limited to 2°C, a 50% reduction in emissions occurred in the 2040s, with net zero reached in the 2070s (Riahi *et al.*, 2022).

These scenarios don't require emissions to be reduced evenly across sectors – the most cost-effective scenarios show the energy supply sector reaching net zero before the economy as a whole. Emissions reductions are highly dependent on electrification in industry and transport, and crucially require increased electricity generation from low- and no-carbon sources. Low- to no-carbon electricity will need to provide a share of between 65% and 92% by 2030, and over 98% by 2050, to limit warming to 2°C or less (Höhne *et al.*, 2022).

Riahi *et al.* (2022) found that pathways that limit warming to 2°C or less also require some degree of carbon dioxide removal (CDR) to achieve emissions targets, ranging from under 1Gt CO_2 per year to 15Gt CO_2 per year in 2050.

The role of CDR in these pathways varies depending on the underlying scenario. CDR can accelerate the pace of emissions reductions and offset residual emissions from hard-to-abate sectors. Or, in the case of an emissions and/or temperature overshoot, CDRs can be scaled to create net-negative emissions and return to the target atmospheric CO_2 concentrations. (Figure 1)

Figure 1: Net global greenhouse gas and CO_2 emissions from the representative pathways assessed in AR6, relative to the projected emissions from current NDCs and policies (red line) and implemented policies and 2030 pledges (salmon shading). Figure citation: Figure 3.6 in Riahi *et al.* (2022)



In the scenarios assessed in AR6, the CDR options primarily consisted of afforestation, bioenergy with carbon capture and storage (BECCS), and direct air carbon capture and storage (DACS). The report notes that, at scale, both BECCS and afforestation can lead to widespread changes in land use and land cover, including increases in forest cover and an increase in cropland devoted to energy crops.

Although CDR was included in almost all scenarios, meeting the 1.5°C target with no overshoot was most common in scenarios that had the smallest contribution of net negative emissions. These scenarios relied on early and large reductions in emissions of CO_2 and non-CO_2 GHGs. For scenarios with the steepest reductions in all GHGs, no negative emissions were needed by 2100. However, these scenarios aren't consistent with current NDCs; following these scenarios would require rapid and substantial action to reduce emissions (Rogelj *et al.* 2022).

For the AR6, Riahi and colleagues (2022) created a set of five illustrative mitigation pathways (IMPs) that limit warming to 1.5 or 2°C. Each pathway maximises a different tool or lever for minimising reductions, with variations in the timings of how quickly mitigation measures are put in place.

Two of these scenarios focus on a critical role for CDR. The IMP-Neg scenario – which places much greater emphasis on the deployment of negative emissions technology – limits warming to 2°C, with temperatures falling to 1.5°C by the end of the century. The IMP-GS scenario also employs substantial CDR to counter a slow roll-out of mitigation measures, and limits warming to 2°C.

The three remaining scenarios limit warming to 1.5 °C. The IMP-LD scenario looks at the effects of changing consumption patterns to reduce demand for resources, and the IMP-SP scenario focuses on shifting global pathways to sustainable development. The IMP-Ren scenario emphasises the rapid roll-out of solar and wind energy.

The International Energy Agency's Net Zero Emissions (NZE) scenario – developed in 2022 – proposes a pathway by which the energy sector can achieve net zero by 2050 (IEA, 2022). Starting from baseline energy emissions and markets in 2021, this scenario achieves a 90% reduction in emissions from the energy sector in 2050, with Gt-scale CO_2 removals needed to offset the residual emissions. This scenario sees a ramp up in annual CDR from 2Mt in 2021 to 240Mt in 2030, reaching 1.4Gt CO_2 in 2050. In this scenario, temperatures peak at 1.6°C of warming around 2040, dropping to an average warming of 1.4°C by the end of the century.

The 1.5°C pathway for energy systems developed by the International Renewable Energy Agency (IRENA, 2022) places a stronger emphasis on CDR than those previously described. It requires annual removals of 1Gt CO_2 in 2030, scaling rapidly to 5Gt CO_2 per year in 2050. This scenario also calls for a rapid transition to low-carbon electricity generation and the electrification of industry and the built environment. In addition, it requires the deployment of carbon capture and storage (CCS) to residual emissions from industry, blue hydrogen creation, and the use of fossil fuels.

The World Resources Institute (WRI) highlights the need for CDR in its synthesis and analysis of existing energy scenarios (Boehm *et al.*, 2022). It also notes that deployment of technological CDR is "well off track" of the removals target of 75Mt CO_2 per year by 2030 and 4.5Gt CO_2 per year by 2050.

Substantial acceleration of the development of technology, infrastructure, policy and financing is needed to realise the potential for CDR. Boehm *et al.* (2022) argue there's sufficient momentum to bring about the changes needed to meet their initial target. They highlight the voluntary carbon market, and companies setting net zero targets through the Science Based Targets initiative (SBTi), as factors. However, their report does caution against the over-prioritisation of removals, which may pull investment and R&D focus away from emissions reductions.

The International Institute for Sustainable Development (IISD) raised a similar point of caution in its report about the state of the energy transition (IISD, 2022). The report discusses the technological readiness of CDR solutions, none of which have been deployed at scale to date. It also addresses the amount of land required for methods such as reforestation and afforestation. In this report's assessment, scenarios that minimise total costs rely more heavily on later removals of CO_2, rather than aggressive emissions reductions. Delays in emissions reductions tend to lead to overshoots in climate models (Riahi *et al.* 2022). If CDR failed to meet the forecasted magnitude in the 2040s and 2050s, it would become difficult if not impossible to limit warming to 2°C or less.

The bulk of evidence from these sources suggests that CDR should be pursued as an important mitigation tool alongside efforts to deliver steep and lasting reductions in emissions. The aim is to reach net zero emissions as soon as possible, and no later than 2050 (e.g. Fankhauser *et al.* 2022). CDR is also likely to be needed to counter ongoing emissions from climate disturbances to ecosystems, for instance, thawing permafrost or increased wildfire activity (Allen *et al.* 2022).

Net zero and carbon removals in policy

The NDC process excludes specific requirements for net zero pledges. As of September 2022, 88 parties had adopted some form of policy declaring a net zero target, out of the 146 NDCs that contained GHG targets (Kuramochi *et al.*, 2022). There's considerable variation in the factors contained within these pledges and policies, even within the G20. They vary in terms of the GHGs covered, the sectors included in the target, and how removals are treated (e.g. whether international removals or offsets can be included in the accounting). The targets also differ as to when emissions will peak, and when net zero will be reached. Only one of the G20 members, Germany, has pledged to reach net zero before 2050 (Kuramochi *et al.* 2022).

Smaller political entities, such as cities and towns, and corporations have also begun to register net zero pledges and targets. There's no specific regulation around these pledges, but many companies have chosen to commit to science-based targets, which are validated by the Science

SBTi. The SBTi Net Zero Standard focuses on emissions reductions over removals, typically requiring companies to reduce emissions by about 90% in the long term before neutralising residual emissions through offsets such as carbon removals (SBTi; 2023). This focus on ensuring steep and rapid emissions reductions is consistent with the conditions for net zero proposed by Fankhauser *et al.* (2022). It ensures that companies can only be validated as net zero if they've worked to reduce emissions throughout their activities and supply chains.

SBTi-validated targets necessitate investment in emissions reductions rather than offsetting or removals technology. However, there's an order of magnitude gap in the committed finance flows from 2011 to 2020 to the estimated US$ 4.3 trillion per year needed by 2030 (Climate Policy Initiative, 2022). The Climate Policy Initiative urges greater mobilisation of private finance; until now, it's been overwhelmingly directed towards the development of low- and no-carbon energy production. To meet climate goals, increased finance will also need to be directed towards mitigation and adaptation in the agriculture, forestry and other land use (AFLOU) sectors. There's also a recognition that investment's now required to develop and scale removal technologies to counter residual emissions, and potentially to support more aggressive removals if emissions reductions targets aren't met.

The SBTi (2023) refers to this as "beyond value chain mitigation" and recognises the importance of investment in offsetting technology as a part of the mitigation hierarchy. In June 2023, the Voluntary Carbon Markets Integrity Initiative (VCMI) launched a scheme for early adopters of its Claim Code of Practice. Under this initiative, companies on track to meeting their SBTi near-term emissions reductions target can make a claim. This would be on the basis of purchasing and retiring high-quality carbon credits representing mitigation of emissions beyond their value chain (VCMI, 2023). The Claim Code of Practice is expected to stimulate and support the emerging voluntary carbon market whilst developing strict standards for validity and credibility. Development now will allow the market to reach maturity in time to support net zero pathways and targets.

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