Comment

JULIA DUNLOP/CLIMEWORKS

Climeworks' plant for direct air capture in Iceland removes carbon dioxide permanently from the atmosphere.

Microsoft's million-tonne CO_2-removal purchase — lessons for net zero

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Strengthen markets, measures and definitions for removing carbon dioxide from the atmosphere to fight climate change.

In January this year, Microsoft made a major announcement: it had paid for the removal of 1.3 million tonnes of carbon dioxide from the atmosphere. Among its purchases were projects to expand forests in Peru, Nicaragua and the United States, as well as initiatives to regenerate soil across US farms. Microsoft will pay the Swiss firm Climeworks to operate a machine in Iceland that pulls CO_2 from the air and injects it into the ground, where it mineralizes and turns to stone. The amount of CO_2 to be removed is equivalent to about 11% of the annual emissions from Microsoft's value chain; of this, the company will count less than half as being certified to officially compensate for its emissions. It is the largest corporate procurement of carbon removal so far.

Microsoft did this as part of its 2020 commitment to slash its greenhouse-gas emissions to 'net zero' — as one of more than 120 nations and 1,500 companies to set such goals[1]. By 2030, the company will reduce its emissions by half or more, and will have 100% of its electricity consumption matched by zero-carbon energy purchases. It will electrify its vehicle fleet, stop using diesel for backup energy and

reduce emissions across its value chain. Emissions that are harder to abate, including historical emissions, will be compensated for by withdrawing carbon from the atmosphere. The firm is levying an internal carbon tax across all types of greenhouse-gas emission. It has set up a US$1-billion fund to invest in carbon reduction and removal technologies, and partnerships to provide social and environmental benefits. The aim is that, by 2030, the company will be carbon negative. By 2050, it will have removed all of its emissions since it was founded in 1975.

Here we summarize the lessons learnt from Microsoft's carbon-removal efforts, along with those from another early corporate procurement — the $9-million purchases of carbon removal in 2020 and 2021 by the US–Irish financial-infrastructure company Stripe. Although these are just two companies' efforts, they are the first significant open solicitations focused exclusively on carbon removal. We write as a team composed of Microsoft staff working on the company's carbon-negative programme and research scientists who analyse carbon reduction and removal strategies.

We highlight three 'bugs' in the current system: inconsistent definitions of net zero, poor measurement and accounting of carbon, and an immature market in CO_2 removal and offsets. These challenges need to be overcome if the world is to reach net zero by mid-century.

Three lessons

First, the supply of solutions capable of removing and storing carbon viably is a tiny proportion of that needed to reach global net-zero emissions by 2050 (which is an anticipated 2–10 gigatonnes of CO_2 per year)[2]. Although Microsoft received 189 proposals offering 154 megatonnes of CO_2 ($MtCO_2$) over the coming years, only 55 $MtCO_2$ were available immediately, and a mere 2 $MtCO_2$ met Microsoft's criteria for high-quality CO_2 removal. Stripe's 47 carbon-removal proposals amounted to 16 $MtCO_2$, but only 0.024 $MtCO_2$ met the company's requirement that carbon remain sequestered for at least 1,000 years (see 'Carbon-market snapshot').

Second, the scarcity of proposals that met the companies' criteria reflects a lack of standards and clear definitions. Roughly one-fifth of proposals to Microsoft focused on avoiding new emissions, not on withdrawing CO_2 from the atmosphere; these were rejected. Others lacked the technical information needed to ensure reliability. Indeed, there's no standard way to measure, report and verify carbon removed. Such ambiguity is a barrier to investment.

Third, systems for accounting for carbon removal do not distinguish between short- and long-term forms of CO_2 storage (see 'Some carbon-removal strategies'). This distorts the market and discourages investments in more-durable solutions. Nature-based storage projects sequestering carbon for less than 100 years accounted for most proposals that Microsoft received (in total, more than 95% of CO_2 volume). It is cheaper and easier to establish trees and enrich soils than to deploy nascent technologies that capture carbon and store it geologically.

On average, in the pitches that Stripe received, biosphere-based storage projects cost only $16 per tonne of CO_2 (tCO_2), whereas geosphere-based storage costs, on average, $141 per tCO_2 ($20–10,000 per tCO_2) — similar to the costs in Microsoft's proposals. Geosphere-based costs are higher, close to the $30–200 per tCO_2 social cost of carbon emissions[3]. However, many factors are not priced in. Nature-based solutions face risks of reversal by fires, pests, storms and changes in land use. These risks can be reduced with insurance and by accounting for carbon across larger areas[4]. But reliable tools for tracking carbon at scale are lacking. Co-benefits such as water conservation, hazard protection and biodiversity are also unaccounted for.

Three priorities

The following three aspects of the world's carbon-removal efforts need urgent attention.

Meaning. The Intergovernmental Panel on Climate Change's definition of net zero is simple enough at a global scale: when "anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals". But it is too broad to tell individual companies how they can reach net zero[5].

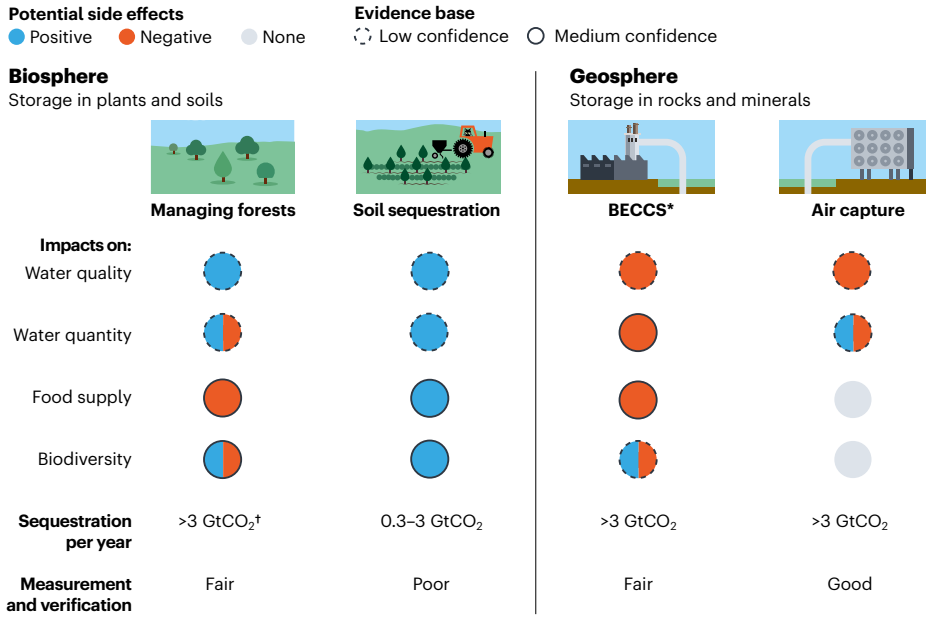
Businesses have lots of options. For example, offsetting emissions — by paying someone else not to emit as a way to compensate for ongoing emissions — can slow the rate at which CO_2 builds up in the atmosphere, but it does not remove any. That's why, in 2020, Microsoft pivoted to purchasing only carbon removal. It also expanded the scope of its programme to include its whole value chain and historical emissions, more than quadrupling the tonnage of carbon that the company needs to compensate for.

Companies need standards to gauge whether their carbon commitments are consistent with global net zero. Efforts to develop them include the international non-profit Science-based Targets Initiative, the Oxford offsetting principles from researchers at the University of Oxford, UK, and the cross-sector business initiative Transform to Net Zero. These emphasize reducing all greenhouse-gas emissions as much as possible along the value chain; setting interim targets; purchasing carbon removal; and shifting towards long-term carbon storage. Such actions must be in addition to those designed to protect and enhance stocks and sinks of carbon in the biosphere.

Many organizations assume there is no limit to carbon-removal possibilities, but there is. Nature-based removal is constrained by area and competing uses of land[6]. Engineering solutions can scale up, but are currently scarce, expensive and resource intensive. Competition for supply will grow as more companies act. The most effective measures might become oversubscribed, making many net-zero commitments impossible to fulfil.

SOME CARBON-REMOVAL STRATEGIES

Nature-based methods for storing carbon dioxide are relatively cheap and currently available. But carbon stored in terrestrial ecosystems is at risk of release by fires and pests, for example. Geological storage could be permanent, but today's technologies are pricey and immature.



Impact ratings are from the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, apart from 'Measurement and verification', which are based on the authors' judgement.
*BECCS, bioenergy with carbon capture and storage; †$GtCO_2$, gigatonnes of CO_2.

SOURCES: IPCC SIXTH ASSESSMENT REPORT (2021)/AUTHORS' ANALYSIS

GETTY

Planting forests and improving their management are nature-based solutions that companies can use to remove and store carbon.

Without rapid growth in supply, the world might run out of high-quality options to compensate for remaining emissions, even after drastic reductions. Too little is being invested in durable technological approaches and geological storage systems.

What can be done? Companies should start by reducing to zero those emissions they have most control over, such as from energy use and land management. In the meantime, they should invest in expanding the supply and lowering the cost of the most effective carbon-removal technologies, as Microsoft and Stripe are doing. Firms should consider purchasing removal for emissions beyond their control that are hardest to abate, such as transport of goods and materials by air and sea.

Researchers need to define a global budget for carbon removal, including evolving scenarios for the supply of nature-based and technology-based removal and storage. And they should assess the future demand for carbon removal driven by net-zero commitments of diverse organizations around the globe.

Social equity is crucial. To reach net zero, developing economies and under-served communities must benefit. For this reason, Microsoft is partnering with Sol Systems, a solar-energy finance and development firm in Washington DC, to create a fund that links the purchase of renewable energy to career training, habitat restoration and clean-energy grants. Similar efforts should be undertaken for carbon removal.

Measurement. Corporations need more-accurate, automated and consistent ways of measuring and accounting for carbon. The non-profit organization Greenhouse Gas Protocol provides guidelines for assessing emissions from internal operations, such as vehicle use and manufacturing, and from purchases of energy sourced off-site. Estimating emissions from supply and value chains is more difficult[7]. It requires calculations from all suppliers and users of a company's products and services. Three-quarters of Microsoft's emissions come from these, including building materials, business travel, product life cycles and the electricity that customers consume when using Microsoft's products. The company has been using expenditure data and industry-average emissions for reporting purposes. But these have large uncertainties and are of limited use in reducing emissions in practice. They do not factor in the impacts of making different choices in the value chain for greenhouse-gas emissions.

> **"Too little is being invested in durable technological approaches and geological storage systems."**

Microsoft is making a start by requiring suppliers to make annual disclosures of their greenhouse-gas emissions and to adopt plans to reduce emissions. However, suppliers face a plethora of carbon-reporting requests.

Digital tools are emerging that can automate and increase the accuracy of emissions measurement. Systems that combine remote-sensing images, sensors and machine learning are being developed – for example, the European Space Agency's Copernicus CO_2 monitoring mission and the methane-tracking satellite MethaneSAT, backed by the non-profit Environmental Defense Fund in New York City.

Microsoft's FarmBeats team is developing low-cost, scalable methods for measuring soil carbon in agricultural fields. Microsoft is also collaborating with start-ups, such as NCX (formerly SilviaTerra) in San Francisco, California, to process terabytes of satellite imagery to count trees in the United States, estimate their potential for carbon sequestration and create a marketplace for private landowners to reduce deforestation. For projects such as these to succeed, rural broadband will be needed to collect and transmit data from networks of Internet-connected devices – the Internet of Things.

A growing number of enterprise-software companies, including SAP in Walldorf, Germany, Salesforce in San Francisco and Microsoft, are developing platforms for automating carbon accounting. For example, Microsoft's Cloud for Sustainability connects organizations to real-time sources of data to track carbon and show performance against net-zero goals. Such platforms are still in their early stages, however.

Automated systems will become more important as greenhouse-gas reporting and emissions reductions become mandatory — as the leaders of the G7 group of countries announced in June that they would implement. Investors and customers increasingly demand that companies demonstrate progress against environmental, social and corporate-governance goals. National governments are drafting regulations for corporate climate-related disclosure. These rules could help to create common standards for carbon accounting and climate-change data.

Markets. Companies need better economic incentives to promote the most effective forms of CO_2 removal. Nature-based removal and storage, and technology-enabled removal and geosphere-based storage are not equivalent commodities and should not be valued as such.

Today's pricing on a per-tonne basis encourages companies to buy the lowest-quality carbon offsets. It does not monetize the duration of carbon storage, the risk of premature release, or the social equity or environmental benefits of removal. At current prices, credits for avoided emissions are the cheapest (as low as \$3 per tCO_2). Nature-based carbon-removal costs more (\$5–50 per tCO_2), although it is much less expensive than geo-based removal.

Price and supply will shift over time. The cost of nature-based removal is likely to increase as the requirement increases and supply declines, as available forests and soils become saturated. Meanwhile, geo-based technologies will develop and scale up, becoming more accessible and cheaper. Companies making commitments to become net zero by 2050 have to make decisions now about operations in 30 years' time, yet there is little economic modelling to project how CO_2-removal markets might change.

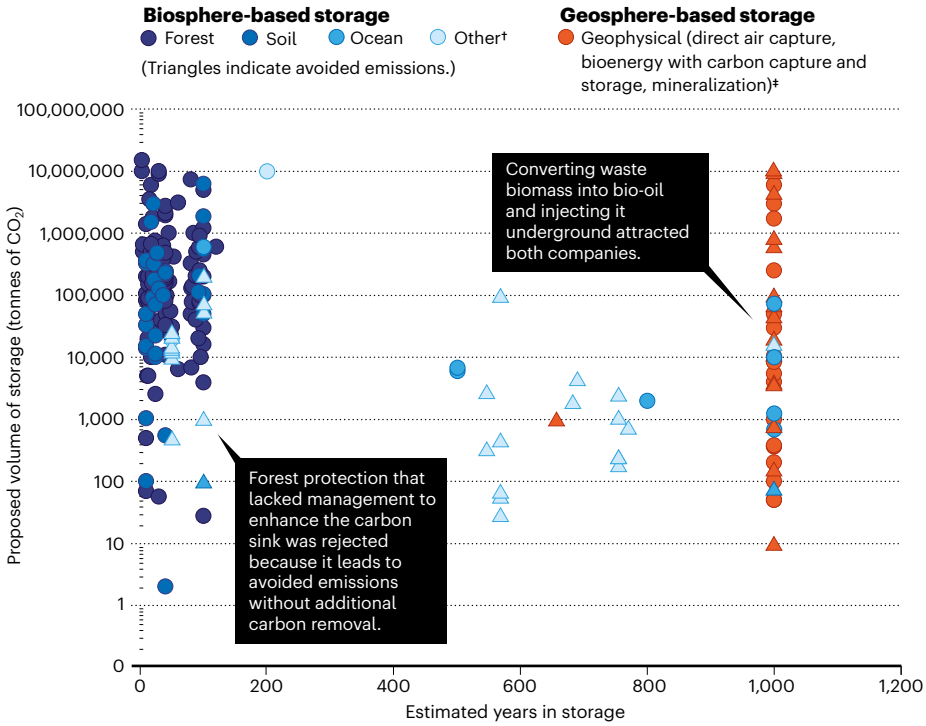
"Companies need better economic incentives to promote the most effective forms of CO_2 removal."

Governments, researchers and companies need to develop a robust and effective carbon-removal market that can meet the demand for global net zero. A key advance would be to set consistent standards for measuring, verifying and accounting for carbon removal that internalize differences in the quality and durability of carbon stored in the biosphere and the geosphere. Multiple approaches have been proposed[8,9]. However, these comparisons hinge on choices of a few parameters, such as economic rates. Factors such as competition for land use, limits to ecosystem-carrying capacity and social and environmental impacts need to be accounted for.

Microsoft is currently executing a strategy for its investments over the next decade, while setting conditions for the next three decades. The company is prioritizing funding across three pillars: reducing greenhouse-gas emissions; removing carbon from the atmosphere and storing it in the biosphere; and removing and storing it in the geosphere. It is implementing internal targets, grants and other incentives to encourage innovations in emissions reduction. Nature-based solutions will be a major portion of its carbon-removal strategy in the near term. The company will include more geo-based storage as this becomes more widely available. To hasten that day, Microsoft, through its \$1-billion Climate Innovation Fund, is investing in projects such as the Orca direct-air-capture facility in Iceland developed by Climeworks. Anyone who can do more should do more. It is time to step up to develop the science, technology and markets for successful carbon removal.

CARBON-MARKET SNAPSHOT

In 2020, Microsoft and financial-services firm Stripe received 189* and 47 proposals from companies, respectively, for locking away carbon dioxide. Of these, 95% used nature-based storage, which is less durable than geosphere-based. Few options were available for permanent removal. Only about 2 million tonnes' worth was judged reliable enough to purchase, of the around 170 million tonnes offered.



*Data on 161 proposals compiled by CarbonPlan (https://carbonplan.org); these exclude 28 further proposals to Microsoft that lacked sufficient information. †Biomass, wood products and biochar. ‡Many geosphere-based solutions were classified as >1,000 years duration, but are shown here as 1,000 years for simplicity.

SOURCES: CARBONPLAN/AUTHORS' ANALYSIS

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The authors declare no competing interests.