THE STATE OF
Carbon Dioxide Removal

A global, independent scientific assessment of Carbon Dioxide Removal

1st EDITION
EXECUTIVE SUMMARY

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Executive Summary

Scaling up Carbon Dioxide Removal (CDR) is an urgent priority, as are efforts to rapidly reduce emissions, if we are to meet the temperature goal of the Paris Agreement. Scenarios for limiting warming to well below 2°C involve removing hundreds of billions of tonnes of carbon dioxide (CO_2) from the atmosphere over the course of the century. **Drawing together analysis across several key areas, this report is the first comprehensive global assessment of the current state of CDR.**

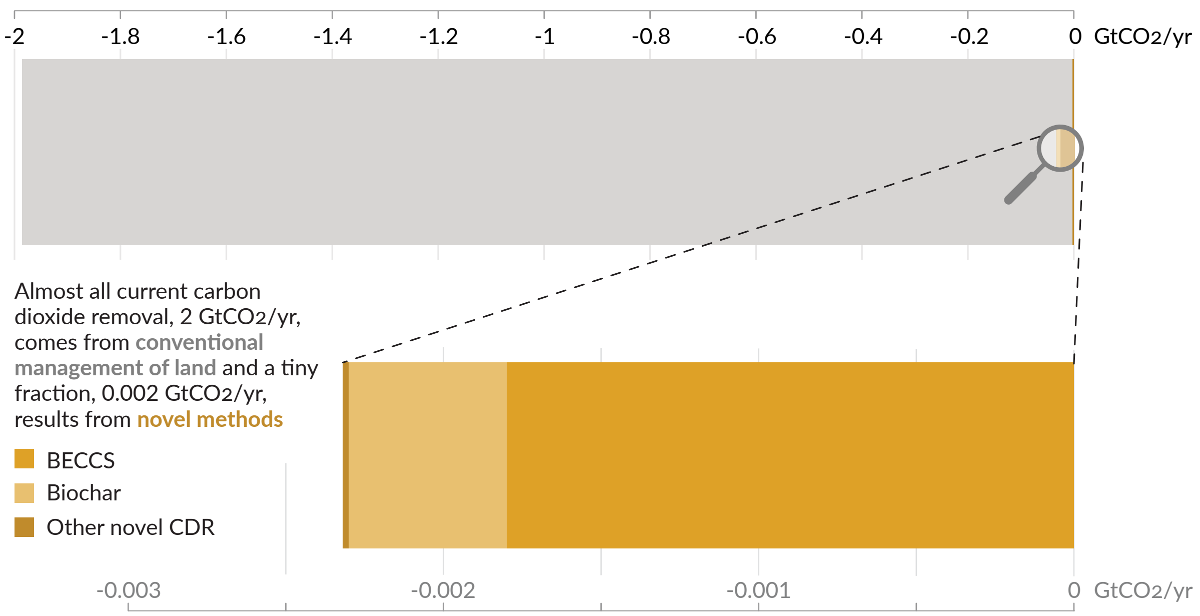
We find a gap between how much CDR countries are planning and what is needed in scenarios to meet the Paris temperature goal. The size of the "CDR gap" differs across scenarios, depending on how we choose to transform the global economy towards net-zero emissions. **However, there are currently few plans by countries to scale CDR above current levels, exposing a substantial shortfall.**

CDR involves capturing CO_2 from the atmosphere and storing it durably on land, in the ocean, in geological formations or in products. Examples include reforestation, biochar, Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS). **For the first time, this report compiles an estimate of the total amount of CDR currently being deployed around the world.**

Almost all current CDR (2 $GtCO_2$ per year) comes from "conventional" CDR on land, primarily via afforestation, reforestation and management of existing forests. Scenarios that limit warming to 1.5°C or 2°C require further increasing current forest sinks, as well as minimising emissions from deforestation. By 2050, land-based removals approximately double in 1.5°C pathways and increase by around 50% in 2°C pathways compared to 2020 levels. **In the near term, several countries plan to *maintain or slightly increase* conventional CDR on land by 2030, which is on its own a huge challenge requiring dedicated policies and management.**

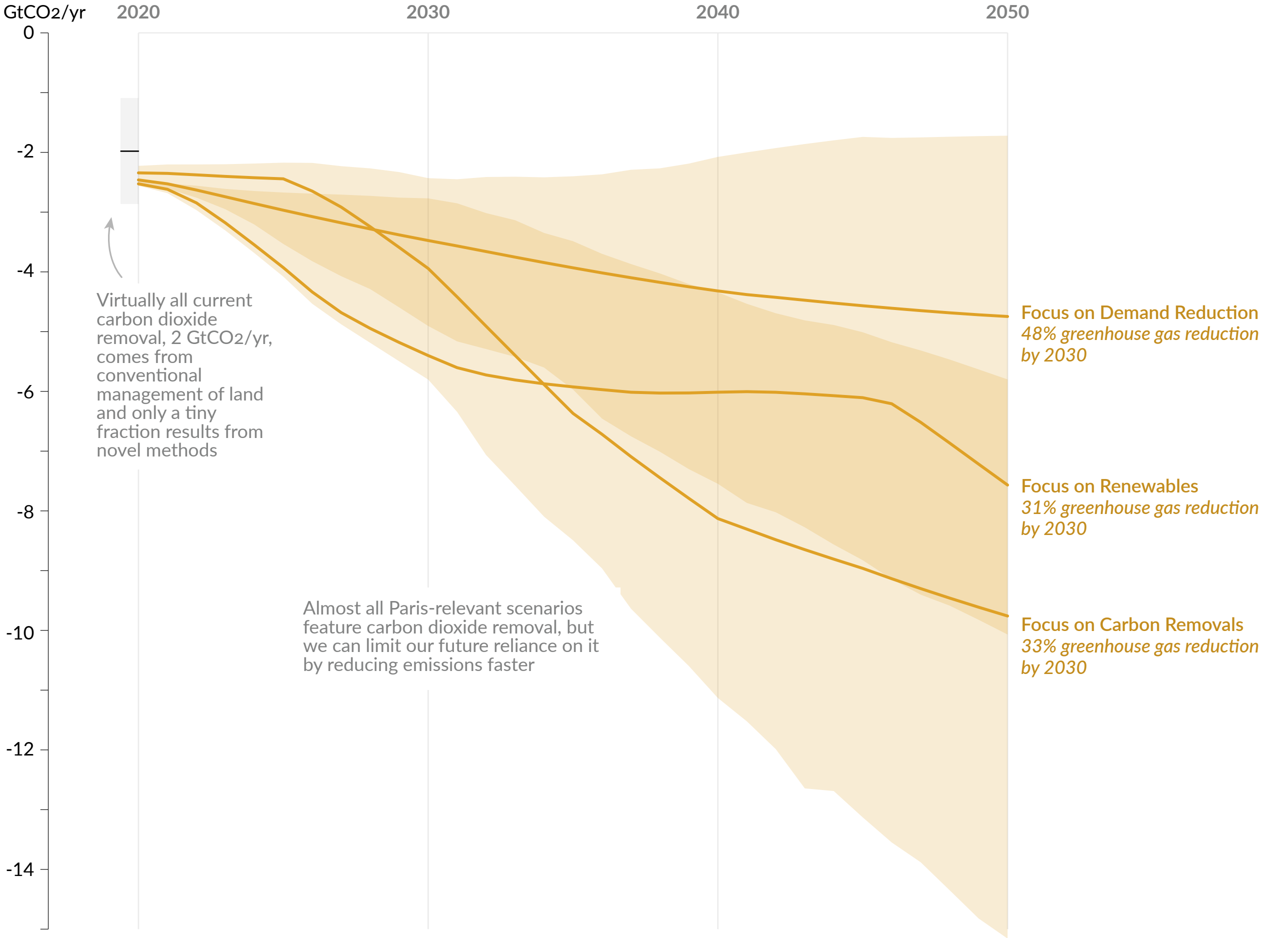
Only a tiny fraction of all current carbon dioxide removal results from novel methods

Total current amount of carbon dioxide removal, split into conventional and novel methods ($GtCO_2$/yr)



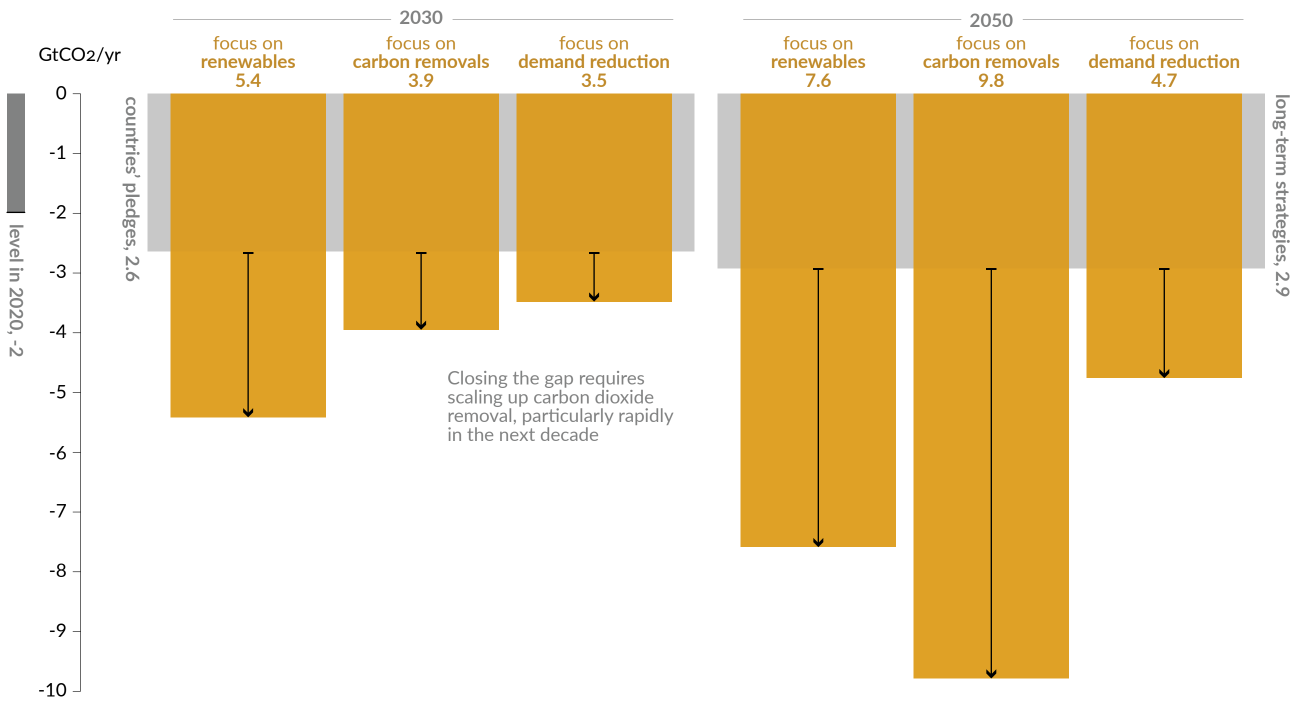
Carbon dioxide removal is a feature of all scenarios that meet the Paris temperature goal, in addition to reducing emissions

Carbon dioxide removal (GtCO2/yr), in 2020 and in three Paris-consistent scenarios



There is a ↧ gap between proposed levels of carbon dioxide removal and what is needed to meet the Paris temperature goal

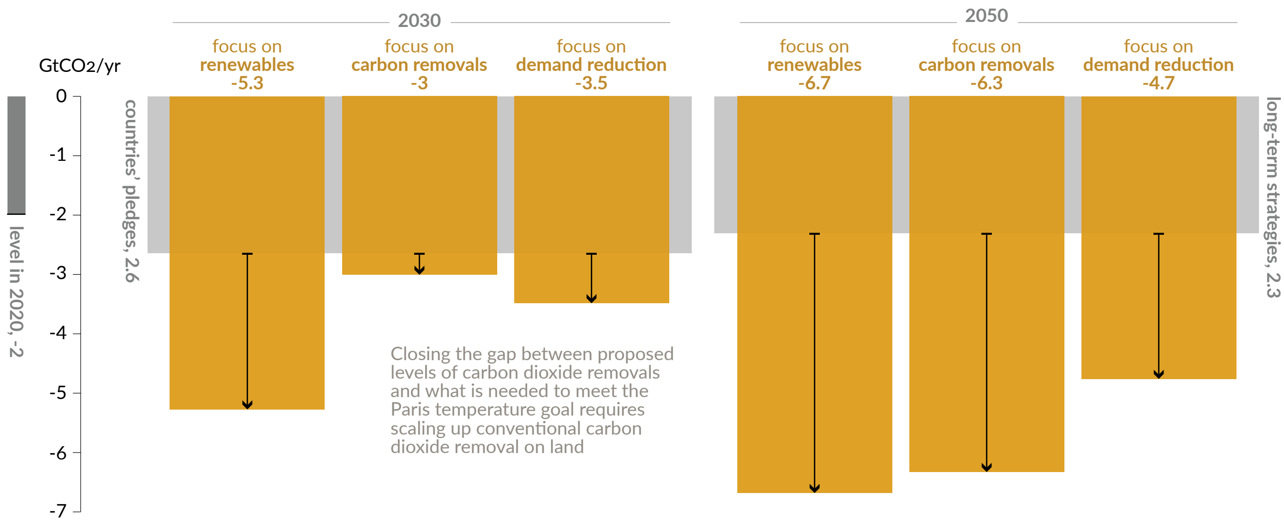
Carbon dioxide removal (GtCO2/yr), proposed levels compared to three Paris-relevant scenarios in 2030 and 2050



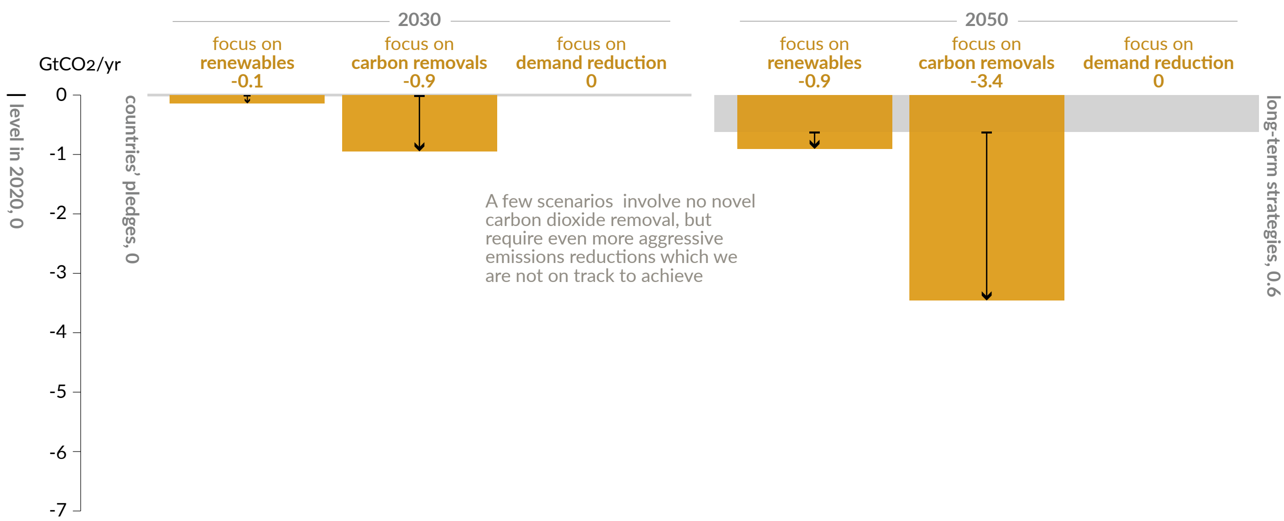
Virtually all scenarios that limit warming to 1.5°C or 2°C require "novel" CDR, such as BECCS, biochar, DACCS, and enhanced rock weathering. However, only a tiny fraction (0.002 $GtCO_2$ per year) of current CDR results from novel CDR methods. **Closing the CDR gap requires rapid growth of novel CDR.** Averaging across scenarios, novel CDR increases by a factor of 30 by 2030 (and up to about 540 in some scenarios) and by a factor of 1,300 (up to about 4,900 in some scenarios) by mid-century. Yet no country so far has pledged to scale novel CDR by 2030 as part of their Nationally Determined Contribution, and few countries have so far published proposals for upscaling novel CDR by 2050.

There is a ↧ gap between proposed levels of carbon dioxide removal and what is needed to meet the Paris temperature goal

A. Conventional carbon dioxide removal (GtCO2/yr), proposed levels compared to three Paris-relevant scenarios in 2030 and 2050



B. Novel carbon dioxide removal (GtCO2/yr), proposed levels compared to three Paris-relevant scenarios in 2030 and 2050



CDR is not a silver bullet, as scenarios that limit warming to 2°C or lower require deep cuts to emissions in addition to, not in place of, CDR. A few scenarios do meet the Paris temperature goal without novel CDR, but these require even more aggressive emission reductions, which we are not on track to achieve. To help manage uncertainties and risks associated with CDR at large scales, our dependence on it should be limited by reducing emissions faster.

Spurring the rapid growth in CDR necessary to close the CDR gap requires urgent and comprehensive policy support that is tailored to specific national contexts. Over 120 national governments have a net-zero emissions target, which implies using CDR to counterbalance residual emissions, but only a few explicitly integrate CDR into their climate policies. **The next decade is crucial for novel CDR, in particular, since the amount of CDR deployment required in the second half of the century will only be feasible if we see substantial new deployment in the next ten years, novel CDR's formative phase.** Yet our assessment reveals few countries have actionable national plans to develop CDR, particularly for novel methods.

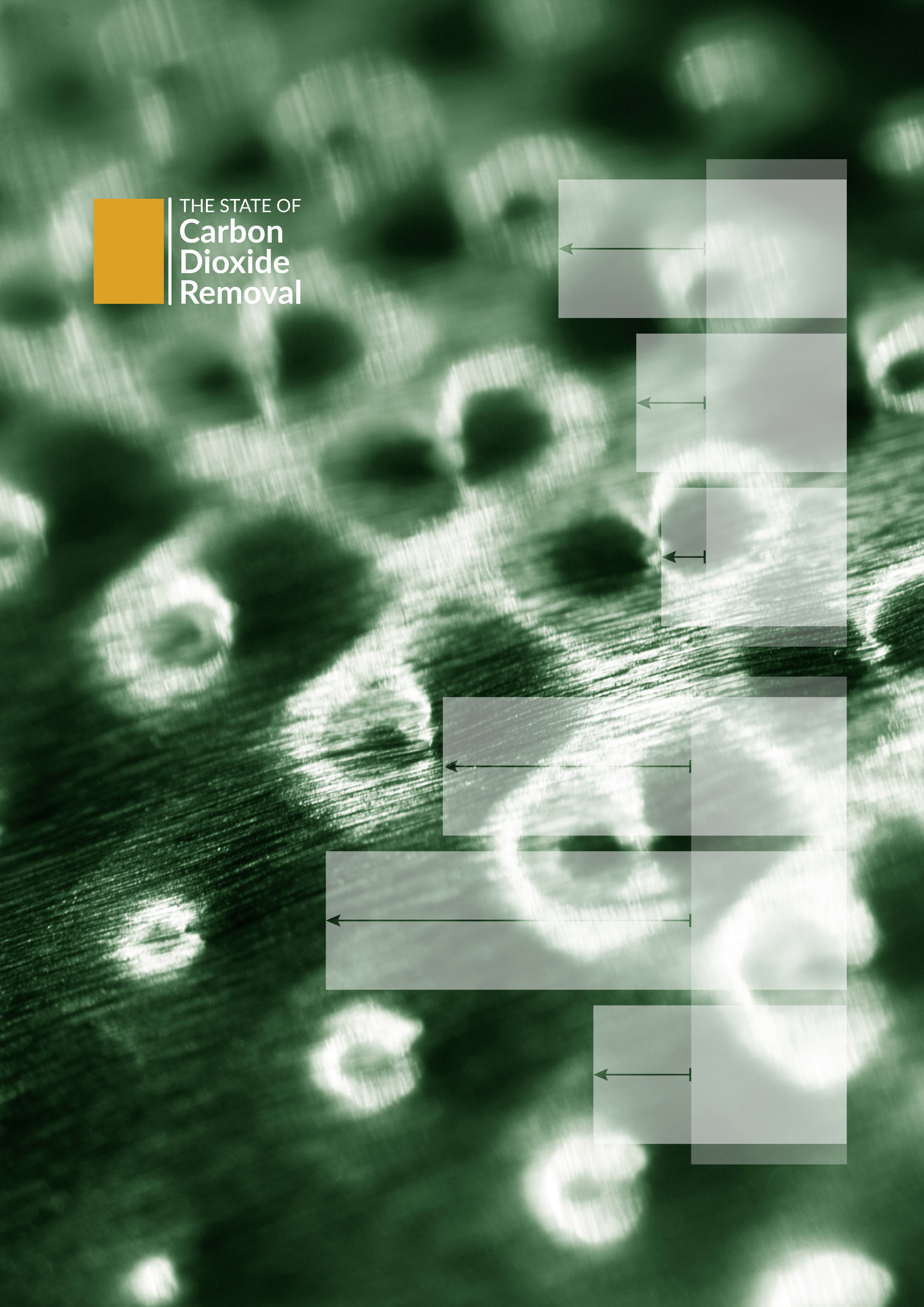
In terms of recent growth, our assessment of trends in the scientific literature, innovation and public perception of CDR reveal some interesting patterns as CDR evolves. **The peer-reviewed scientific literature on CDR is growing faster than for climate change as a whole, now consisting of over 28,000 English-language studies.** Most focus on land-based biological CDR methods such as biochar and soil carbon sequestration. Almost all are published in science and technology journals, with very few in social sciences or humanities publications, and only about a third have a specific geographic focus. This indicates a potential lack of information tailored to specific local contexts, particularly for novel CDR methods.

Innovation in CDR has expanded substantially in recent years. We see evidence of this in over $4 billion of publicly funded Research, Development and Demonstration (RD&D), a rise in patents (with China the lead country and Direct Air Capture the most patented technology) and investment in new CDR capacity totalling approximately $200 million from 2020 to 2022. **CDR is becoming more of a public talking point too, although awareness remains low relative to other aspects of climate change.** A growing number of scientific studies on how people perceive CDR indicate public support for research into CDR but raise concerns about deployment at scale. CDR methods that are familiar and often perceived as natural, such as afforestation, are viewed more favourably than others. Discussion of CDR on the social media platform Twitter is growing fast, with a trend towards more positive sentiment for all CDR methods except BECCS.

The primary policy implications of this first assessment of the state of CDR are that meeting the Paris temperature goal requires us to accelerate emission reductions, increase conventional CDR and rapidly scale up novel CDR. Actionable policy proposals, with standardised transparent reporting and involving societal deliberation, will support and shape these outcomes in a manner that acknowledges both the urgency of the challenge and issues such as policy costs, hazards and land-use conflicts.

We intend for this report to be the first in a series, continuing to track the CDR gap and providing a clear, authoritative, and up-to-date snapshot and serving as an information resource for those who are making decisions about CDR and its role in meeting climate goals. We have identified areas on which future assessments can build, including: (1) **expanding the community** of experts and data sharers to widen the knowledge, perspective and experiences that guide development of CDR; (2) **improving the availability of data** on CDR projects, plans, investment and other relevant dimensions; and (3) honing the analysis around more **complete, consistent and comparable definitions and methods.**

Twenty years ago, renewable energy was a niche sector. Today, the picture is radically different. This rapid development was enabled in part by concerted efforts to build institutions and communities for gathering and sharing information. CDR is at the start of a similar journey. We, the scientific convenors, hope that this contribution, in addition to the contributions of many others, provides similarly important guidance so that CDR too can play an important role in addressing climate change.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