Executive summary

THE STATE OF Carbon Dioxide Removal

A global, independent scientific assessment of Carbon Dioxide Removal

3rd EDITION | 2026

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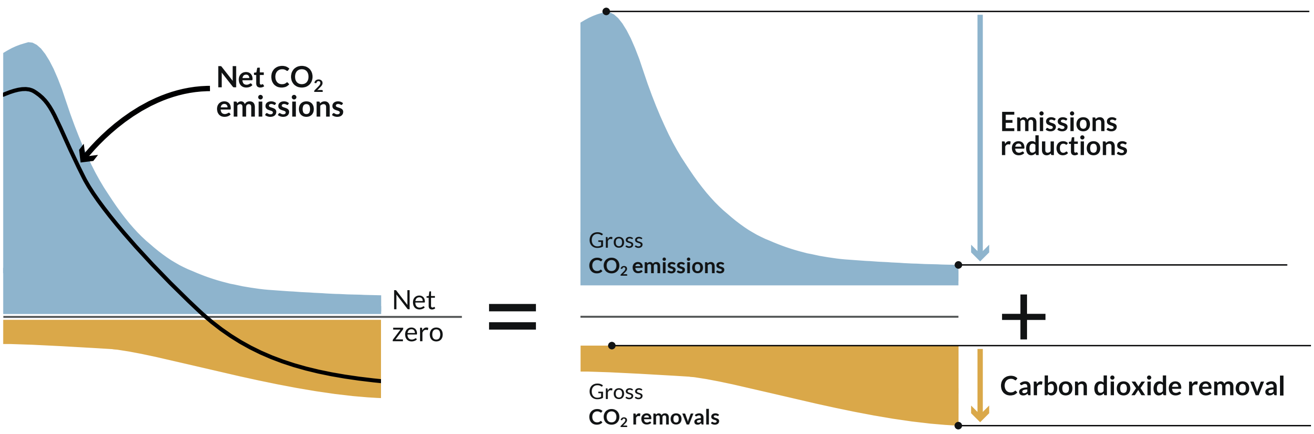
Aerial top-down view of a rocky seashore. By Petar Bonev

Executive summary

1. Both carbon dioxide removal (CDR) and emissions reductions are needed to reach the Paris temperature goal.

CDR consists of human activities capturing CO_2 from the atmosphere and storing it durably in geological, terrestrial or ocean reservoirs, or in products. For as long as any emissions continue, CDR will be needed to halt the rise in global temperature. All scenarios that reach net zero and halt the rise in global temperature deploy additional CDR at gigatonne scale. Across cost-effective scenarios compatible with the Paris Agreement, reductions in emissions contribute at least 80% of the effort to achieve net zero CO_2 emissions, and CDR contributes the remainder.

Both carbon dioxide removal (CDR) and emissions reductions are needed to reach climate targets

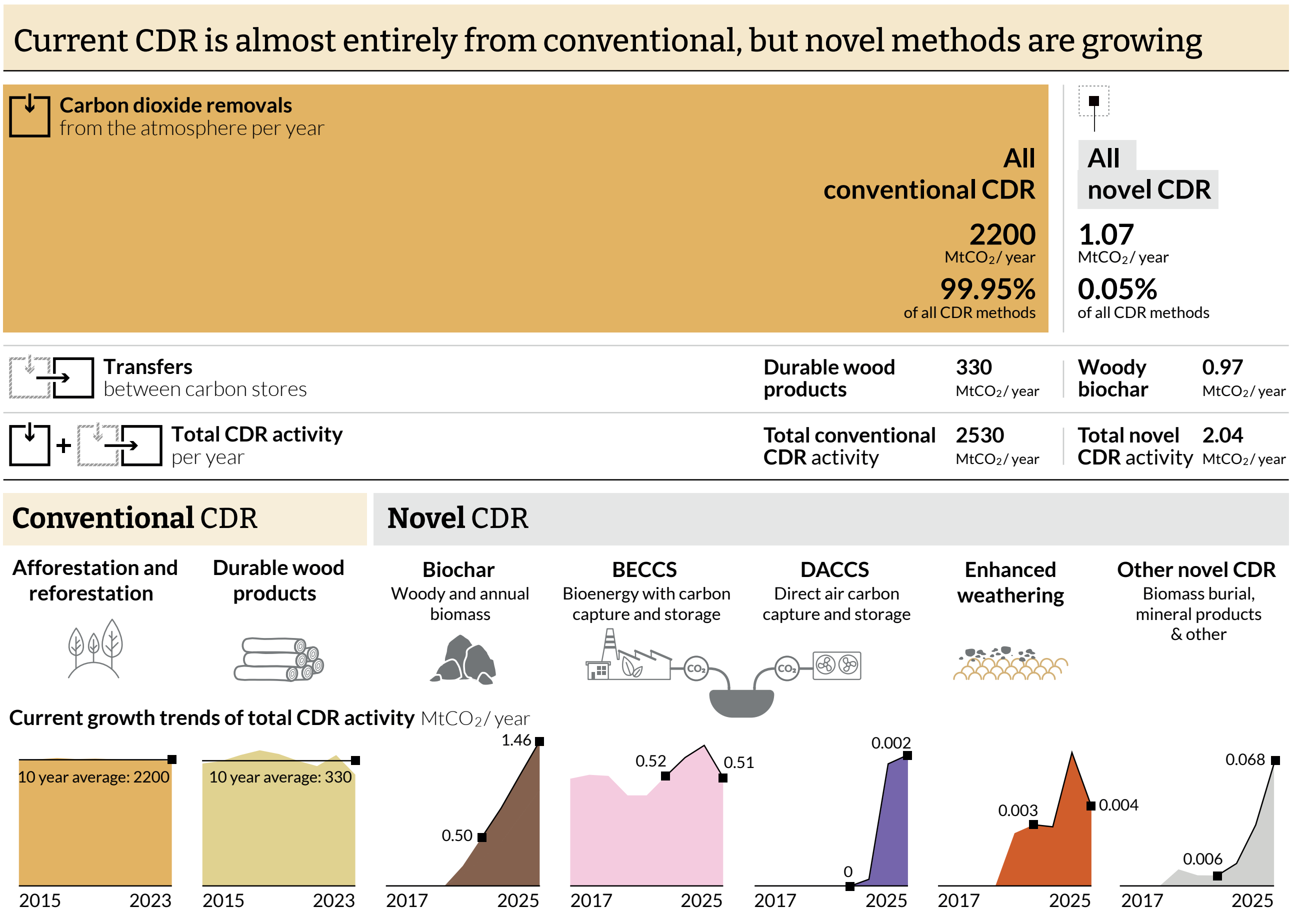


2. There are many CDR methods, and they span large ranges in costs, potentials and social acceptance.

CDR is comprised of “conventional CDR”, well-established methods that largely involve forests and soils, and “novel CDR,” such as biochar, enhanced weathering, and direct air carbon capture and storage. Expected costs for removals vary widely, from less than $10/tonne to over $1000/tonne, with most methods having upper limits exceeding $200/tonne, well above current carbon prices. Large dispersions in cost estimates exist even within each CDR method. For multiple methods, scale-up will depend on costs coming down. Independent removal potentials have similarly large ranges, with the more reliable lower range estimates for most methods around 1 $GtCO_2$ per year. Reasons for uncertainty include low scientific understanding, data availability, inconsistent definitions, and assumptions about sustainability and durability. Costs have those issues plus differences in system boundary definitions, and whether the co-benefits and the costs of monitoring, reporting, and verification are included. Public support is also uncertain. It involves concerns about eco-systems and governance, and depends on engaging diverse publics and conveying local benefits. Public familiarity with CDR is low, and news media coverage of CDR is down even though it is growing as a share of total climate coverage. For each method, proving reliability and effectiveness will be crucial to realizing potentials.

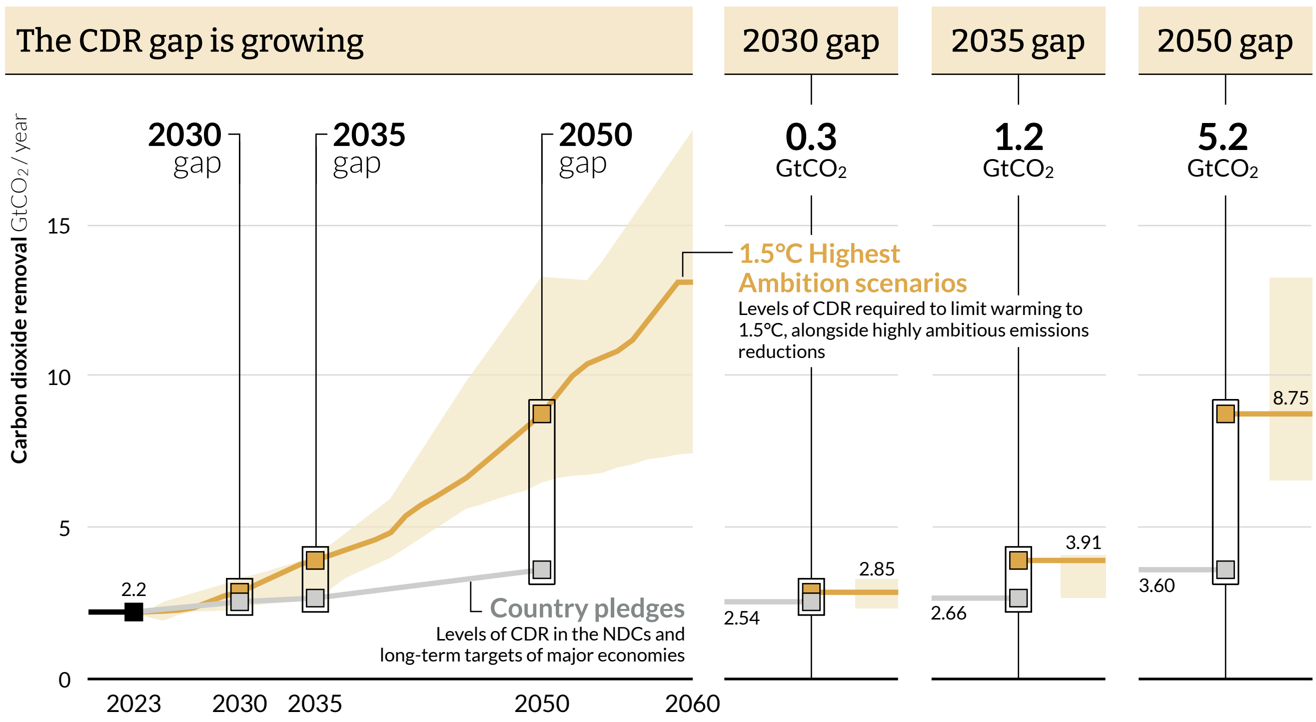
3. Current removal is almost entirely from land-based, conventional CDR; novel CDR is growing quickly but still comprises a tiny fraction of total removal.

Total removal is 2.2 $GtCO_2$ per year, equivalent to 5% of gross CO_2 emissions. Conventional CDR represents 99.9% of this total, with the largest contributions from China, the United States, the European Union, Brazil and Russia. Novel CDR is 0.002 $GtCO_2$ per year and has been growing at 40% per year – similar to successful technologies like solar energy but insufficient for the scale-up required to meet the Paris temperature goal. Biochar and BECCS account for almost all novel removals. These projects plus those in construction would reach 0.008 $GtCO_2$ per year of capacity in 2030, although only 20% of planned capacity has been built in recent years.



4. A large and growing gap exists between the amount of CDR in country pledges and that in Paris-compatible scenarios; both conventional and novel CDR are deployed in every scenario.

Country pledges, taking into account the latest nationally determined contributions, reach 2.5 $GtCO_2$ per year CDR in 2030 – but the median level in the highest-ambition Paris-compatible scenarios is 2.9 $GtCO_2$ per year. This results in a gap of 0.3 $GtCO_2$ per year. To close the 2030 gap, overall ambition needs to roughly double (i.e. from +0.3 $GtCO_2$ per year to +0.6 $GtCO_2$ per year in 2030) through new and revised pledges. The gap rapidly grows to 1.2 $GtCO_2$ per year in 2035 and 5.2 $GtCO_2$ per year in 2050, with pledges in both years falling below levels in all Paris-compatible scenarios. Announcements by companies sum to over 5 $GtCO_2$ per year in 2050, substantially higher than country pledges. But a multi-$GtCO_2$ gap would remain, and credibility in these announcements is low. Only about one-third of countries mention novel CDR in their mid-century strategies. While conventional CDR plays the strongest near-term role, novel CDR scales up by a factor of five between 2030 and 2035 and accelerates to over $GtCO_2$ per year by 2050 in assessed scenarios. Because emissions have continued to grow since the 2nd Edition, so has the CDR gap. It will continue to widen without significant near-term action to reduce emissions.



5. CDR sits in a broader context of multiple goals and side effects.

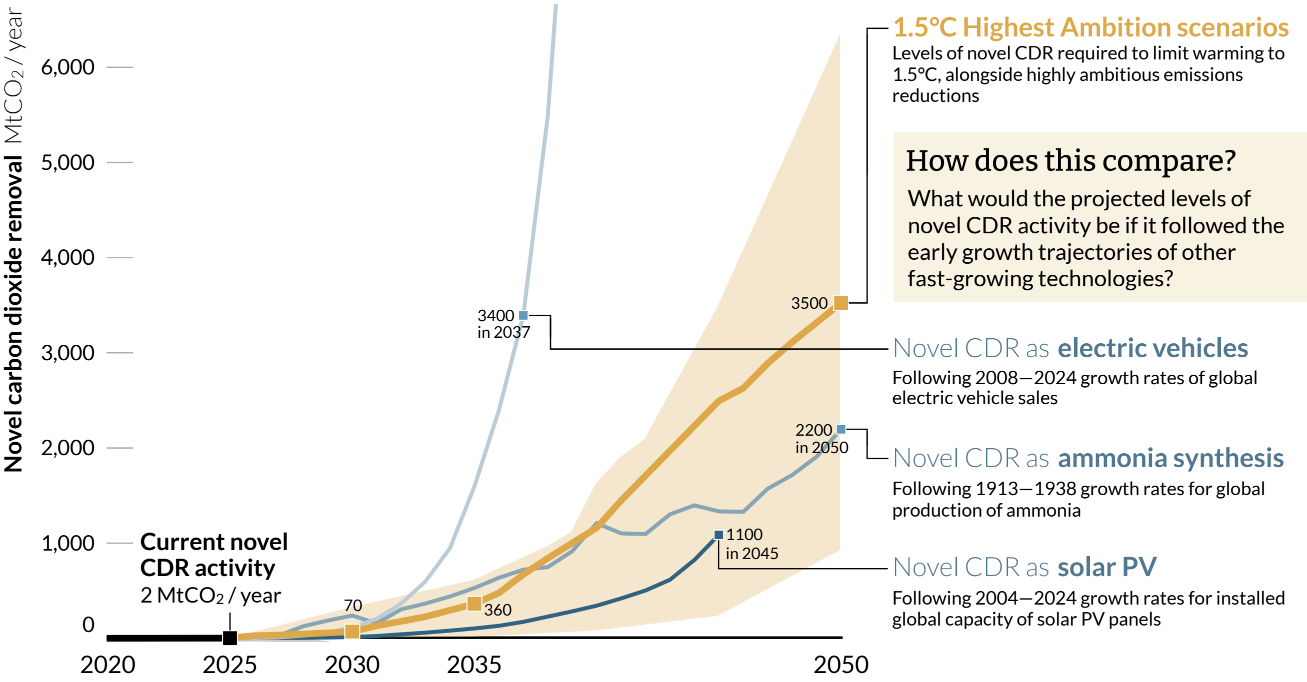
Policies supporting conventional CDR have been implemented for many years and have been motivated by a variety of goals, including ecosystem restoration, biodiversity protection and economic opportunities, as well as stabilizing the climate. Attitudes towards CDR are driven by a wide range of factors including financial payoffs, co-benefits, trust in actors and avoiding harm to ecosystems. Similarly, over half of grant funding for CDR research is for projects described as targeting objectives other than CDR, such as projects focused on wildfires and clean energy. Impacts beyond removing carbon can substantially shape the potential and viability of CDR methods. These side-effects vary by deployment scenarios, typically increase with scale and include consequences for biodiversity, resource consumption, energy use and food production. Some elements of CDR compete with other climate actions (e.g. biomass constraints) while others offer synergies and generate co-benefits. For example, biochar and enhanced weathering can increase crop yields, while durable wood products can avoid the emissions involved in producing similar goods with emissions-intensive processes. Policy design can play an important role in enhancing co-benefits and avoiding harms to produce more sustainable outcomes.

6. Demand for CDR is crucial to closing the CDR gap. While innovative activity has grown, expectations of large and growing demand have become fragile.

R&D, publications, demonstrations, voluntary niche markets and start-up funding in CDR have grown, albeit unsteadily and with some exceptions – particularly high-value patenting, which has declined in recent years. The sustained funding of CDR companies is remarkable given the decline in climate funding overall, of which CDR now accounts for 3%. Last year, contracts for 0.04 $GtCO_2$ of removals were signed in the voluntary carbon market, where purchases from most novel CDR methods come from. Innovation extends to policy innovation with jurisdictions such as the European Union, United Kingdom and Switzerland actively exploring including novel CDR in regulatory schemes. Further, learning by doing is central to innovation, and that depends on expectations of demand, as do other aspects of scale-up. Novel CDR will need to grow at highly ambitious rates, between those seen for solar PV and electric vehicles, which have been the fastest growing climate technologies. Conventional CDR faces different scale-up challenges including competition for land, reversibility, and weakening of the CO_2 fertilization effect as emissions fall. But future demand for CDR has become uncertain. Most policy remains focused on CDR supply, and prices in nascent markets, such as Article 6 of the Paris Agreement and the Carbon Offsetting and Reduction Scheme for International Aviation

(CORSIA), are low compared to the current costs for many methods. Policy dismantling and volatility in the United States are undermining policy credibility and placing pressure on other jurisdictions to adopt policies that will create robust demand and address the CDR gap.

The scaling of novel CDR needed for 1.5°C is very fast but not unprecedented

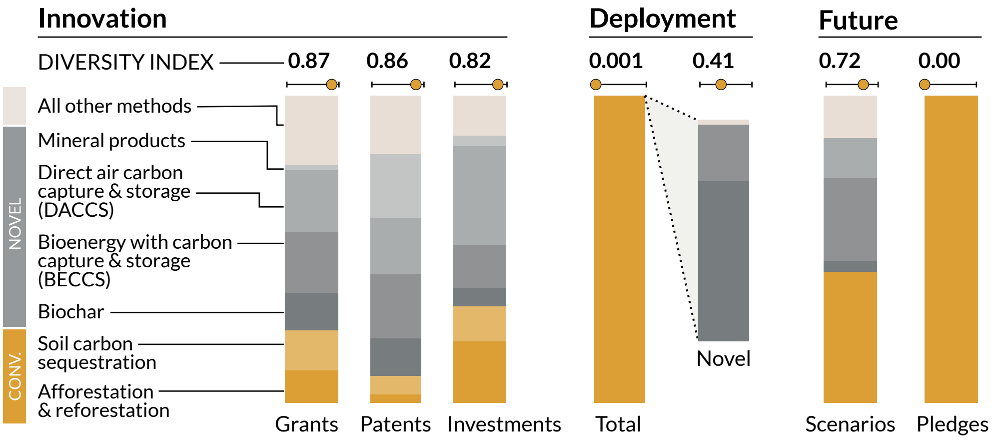


7. Important aspects of the CDR system are highly concentrated, create vulnerabilities, and would benefit from diversification across methods, actors and countries.

Early-stage innovation indicators, such as grants, start-up investments and patents are generally diverse across methods, but later-stage indicators are not. Both CDR deployment and pledges are concentrated in one method (afforestation and reforestation); over two thirds of conventional CDR in voluntary markets is in Latin America; novel CDR is concentrated in two methods (biochar and BECCS); one buyer dominates purchases of novel CDR (Microsoft); most demonstration funding is concentrated in a few countries and projects (Sweden, Denmark and the United States); and start-up investments are focusing on fewer, more mature companies. While first-movers play important roles, if their actions do not diffuse more widely, vulnerability emerges, as evidenced by the impact of US climate policy dismantling and Microsoft's recent adjustments to the pace of its procurement. Further, conventional methods are vulnerable to environmental change and shifting incentives in land use, implying strong benefits to maintaining a diverse portfolio of methods.

A lack of diversity creates vulnerability in the CDR system

Concentration of CDR methods



While indicators of innovation show a high level of diversity across methods, **total deployment and pledges are highly concentrated**

Diversity helps reduce vulnerabilities and enable robust scaling

Concentration of CDR Actors

Voluntary Carbon Market
Most conventional CDR credits come from one region

Novel CDR credit buyers
One buyer purchased most novel CDR credits

Announced pilot funding
Most government funding for novel CDR is in 3 countries

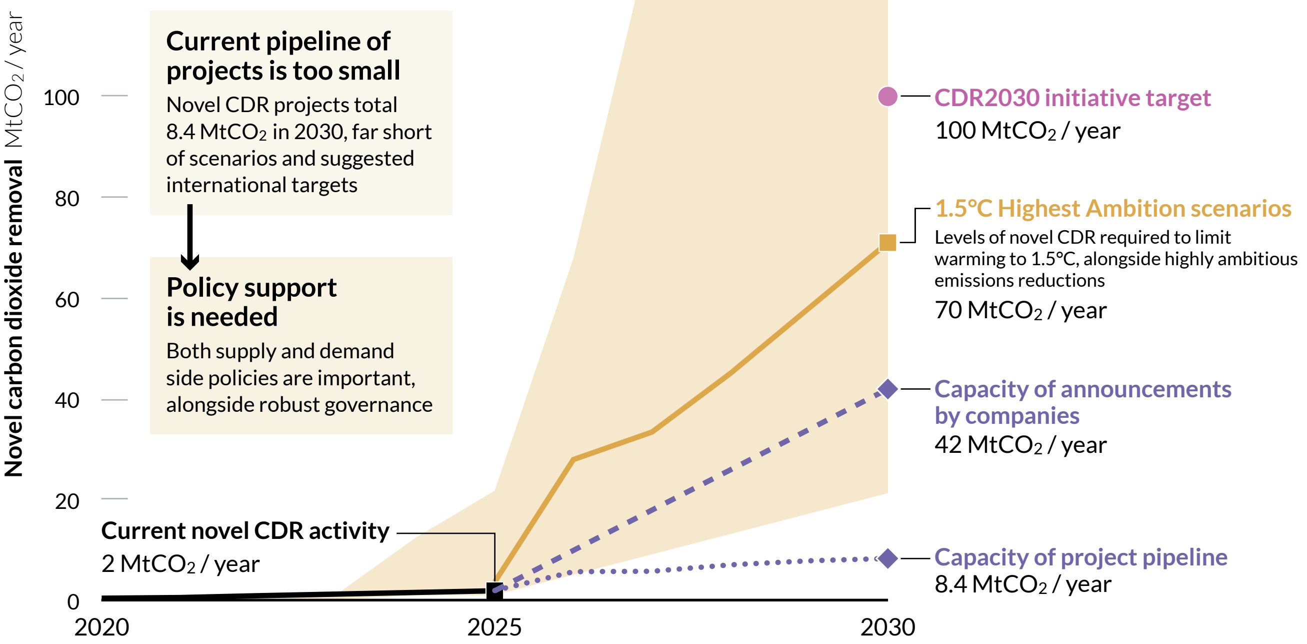
Company investments
Most investments across all CDR are in four companies

Only **a handful of companies and countries currently drive CDR activity and policy support.**
A loss of one of these major actors could compromise CDR development.

8. Closing the CDR gap is urgent because deployment is a gradual process. The period 2026–2030 is thus critical for establishing CDR's role in limiting climate damages.

Delaying emissions reductions would increase the need to deploy removals, especially novel CDR, if the Paris temperature goal is to be met. A ten-year delay in emissions reductions would raise peak temperature and significantly increase cumulative needs for CDR. Dependence on such high levels of CDR (at the upper ends of potentials) risks crossing sustainability thresholds. Conversely, reducing emissions more rapidly would allow for a more moderate scale-up of removals and reduce sustainability pressures related to land, water, ecosystems and resource demands. Novel CDR is in the formative phase, during which it needs to establish legitimacy, prove reliability and grow sufficiently to make its longer-term contribution to the Paris Agreement goal feasible. While CDR activity is generally growing across indicators, several of them reveal fragile support and dependence on a few critical elements. CDR thus urgently needs to overcome these vulnerabilities and develop a robust policy regime. Benefits of policies need to be clear and extend beyond climate goals. International governance can play a key role in coordinating action and disseminating knowledge about what is effective. Above all, the next five years will require policies to establish strong and growing expectations of demand for removals.

The next 5 years are critical for establishing novel CDR

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