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Scaling the Carbon-Removals Economy



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Executive Summary

Over the past 30 years, the world has built the foundations for clean and sustainable economic growth. Entire economies have begun the transition to low emissions: renewable energy is now the cheapest form of power in most regions, electric vehicles are moving from niche to mainstream and global emissions are no longer rising as quickly as once feared. These are historic achievements that would have seemed impossible a generation ago.

But continued progress is not inevitable. While emissions have fallen in some regions, they remain stubbornly high in others. And even where reductions are being delivered, the technologies required to decarbonise sectors like aviation, shipping and heavy industry are still not available at the scale required. Meanwhile, new pressures are emerging: artificial intelligence promises enormous economic gains but may also drive a surge in energy demand, much of which might be met using fossil fuels.

The political context has also shifted. The consensus that once united developed economies around ambitious climate action is fragmenting. Geopolitical competition, economic challenges and populist backlash are testing governments' climate agendas. This makes it harder than ever to sustain the momentum of emissions cuts.

Given these pressures, going forward, the world cannot rely solely on reducing the amount of carbon released into the atmosphere, even while actions to reduce emissions remain the top priority. The world must also actively remove the carbon dioxide that is already in the atmosphere, through the use of carbon-dioxide removals (CDR). The well-known bathtub analogy illustrates that while cutting emissions is like turning off the water (or CO₂) flowing into a bathtub, because the tub is already close to overflowing, we also need to pull the plug (carbon removals) to bring the existing water level down.

At a global level, scaling CDR gives the world three key advantages.

First, CDR provides a pathway to compensate for the residual emissions of the hardest-to-abate sectors, such as cement, chemicals and aviation. Low-cost solutions that address emissions for these sectors don't yet exist at scale and as such, fossil emissions from these will continue for decades to come. Second, removals can strengthen resilience by providing a form of insurance against uncertainty: if emissions don't decrease fast enough, carbon removals can bridge the gap. Finally, these solutions offer an opportunity to manage the risk of temperature overshoot: the very real possibility that global emissions stay too high for too long, leaving the world with no choice but to offset their impact in the future with removals.

There are two main routes to removing carbon: nature-based solutions (such as afforestation and soil carbon sequestration), and "engineered" solutions like biochar and direct air carbon capture (DACC).

Planting trees and investing in nature is critical – and politically appealing – and there are many reasons why the world should continue to support and fund nature-based solutions. But as a tool to offset carbon emissions, we should recognise the limitations of these solutions: they are less durable, prone to reversal, for example through forest fires, and are constrained by land availability.

As such, the world also needs to invest in engineered solutions to capture and remove carbon from the atmosphere. Much of the technology to do this is already available or is under development, but still requires investment, regulatory support and coordination in the near term to help bring the cost down and to get it to scale.

Some critics rightly highlight the high cost of engineered removals today. A tonne of carbon sequestered via DACC, for example, is still many times more expensive than other ways to reach net zero. But the costs of many of these solutions are only likely to fall with deployment and the innovation it brings – as has happened with renewables, batteries and solar panels. And the earlier the world invests in scaling these technologies, the faster and cheaper progress will become, enabling CDR to play a role alongside cutting emissions at their source.

There are also opportunities for individual country leaders to grasp. For landand nature-rich countries, building out nature-based CDR while piloting engineered CDR can strengthen resilience to climate impacts, boost food and energy security, and attract finance for rural development. For wealthier industrialised nations, removals offer an opportunity to build new carbon-management industries that could be central to the future net-zero economy. Permanent CO₂ storage can be the next export opportunity for fossil-fuel economies, turning geology into a service industry by selling durable removals to the world while lowering domestic transition costs. Countries that act early will not only shape the rules, but also capture the jobs, investment and influence that come with them. This is not just pragmatism: if removals are viewed solely as another cost to add to carbon emissions, countries will miss the economic opportunities that these solutions can – and will – provide.

Today the world actively removes around 2 gigatonnes (Gt) of CO_2 per year, 99.9 per cent of which comes from nature-based solutions, while more durable, engineered removals total just millions of tonnes. How to bridge the gap between the current volume of removals and the 5–10Gt needed overall is the focus of this paper, along with the actions required of political leaders to do so.

The world needs a portfolio approach to removals, including those that offer the ability to deliver at scale now and other solutions that lock carbon away for thousands of years. Nature-based removals are low-cost and deployable today, but risk being reversed and are thus relatively temporary, compared to the lifetime of the gases emitted that are resulting in a warming world. In contrast, engineered removals are durable but expensive, and need innovation and scale to make them economic. The pragmatic path blends both: front-loading nature while banking long-term durable carbon storage as engineered CDR scales.

To deliver this portfolio, political leaders should focus on four pillars:

- 1. Establishing integrity. There is currently a lack of agreed global standards on CDR. To be investable, developers, buyers and investors need confidence that a tonne of CDR removed is real, additional, durable, comparable and not double counted. Without clear rules, investors are less likely to fund projects, and credibility is more easily damaged when projects appear to fail. Governments must therefore define and agree what counts as a tonne of carbon removed, set out robust monitoring, reporting and verification (MRV) and permanence rules, and build interoperable digital registries. The governments who set these standards first are most likely to attract investment and set the rules for others to follow.
- 2. Building demand and finance. CDR won't scale until there is a clear answer to the question of who pays. To make CDR projects investable, governments should create predictable demand and de-risk early projects, and provide clarity on how the costs of removals will fall across the private and public sectors. Governments that create reliable demand for removals will capture the investment, innovation, jobs and profits that follow.
- 3. Planning strategically and integrating nationally. Governments should create national CDR strategies to ensure CDR is integrated into industrial strategy and energy, agriculture and land-use planning. This will turn removals from isolated initiatives into part of global industrial and climate cooperation, help countries avoid unintended consequences, and harness the co-benefits from scaling removals such as jobs, improved food security and increased biodiversity.
- 4. Empowering small players and communities. Much of the nature-based removal potential sits with smallholder farmers and local communities. To unlock it, governments should make participation easy and worthwhile by providing technical support and MRV, aggregating small projects so they reach market scale, building capacity to support jobs in local communities and guaranteeing fair benefit-sharing. Carbon removals will only scale if the people who manage the land share in the benefits that deploying these solutions can bring.

Together, these policy actions can help create the credibility, capital, coordination and consensus needed for removals to scale – keeping warming within safe limits and creating co-benefits for the countries that lead.



The Case for Carbon–Dioxide Removals

The breadth of options for carbon-dioxide removal offers a hedge against political and technological underperformance in decarbonisation.

The science is clear: the need for carbon removals is now unavoidable if the world wants to stabilise global temperatures. These should come alongside deep reductions in the use of fossil fuels, which must remain the immediate priority. However, all robust scientific pathways, including from the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), emphasise the need for removals to meet the Paris Agreement temperature goals.² The scale of the removals needed depends on how fast emissions are cut today, but all scenarios suggest that investment is needed now in order to support long-term carbon removal.

Every pathway to net zero, from the most optimistic to the most conservative, recognises the significance of stubborn residual emissions from cement, chemicals, aviation, shipping and other sectors. If emissions cuts are close but not close enough to targets, then removals are the only tool that can be scaled to hit emissions goals. If governments can integrate removals into industrial value chains, they can keep factories open, safeguard jobs and avoid the political costs of premature deindustrialisation. Paired with infrastructure for carbon capture and storage (CCS) that permanently stores CO₂, removals can protect strategic industrial sectors like cement and chemicals while carbon costs ratchet up, shoring up trade narratives and aligning climate goals with a smoother industrial transition.

FIGURE 1

The three key purposes of CDR technologies

SHORT TERM TO LONG TERM Offset residuals in hard-to-abate sectors Reduce CO2 already in the air Further removals of CO₂ after temperature Aviation, agriculture, cement, shipping and industry will retain unavoidable residuals. CDR neutralises those residual emissions. Net-zero pathways still leave ~3-7GtCO₃/yr residuals by 2050. Overshoot = temporarily crossing 1.5–2°C; current track ≈ 2.5–3°C. Early CDR and fast ramp-up makes targets Some options (e.g. afforestation) can scale Overshoot raises tipping-point risks; CDR All pathways include CDR: ~100-1,000GtCO₂ Major firms (e.g. Microsoft, Airbus) are For a ~50% chance at 1.5°C, the remaining by 2100 (2–20 x annual emissions today. • Today's CDR ≈ 2GtCO₂/yr, ~99% land-based. carbon budget ≈ 130GtCO₂, with risk this will investing in durable CDR potentially be used up this decade.

Source: Imperial Grantham Institute (Carbon Dioxide Removal 2024; Pledges and policies: are we on track to meet climate goals?)

These solutions, together with CCS, are thus also industrial policy by another name. Countries that invest early in removal technologies have the potential to carve out a competitive advantage in a market that will likely expand. Just as solar panels and wind turbines became symbols of green industrial policy, so too will facilities for direct air capture, hubs for carbon storage and facilities producing biochar. Early movers stand to capture supply chains, control technology and intellectual property, and generate high-value employment. In a world of carbon border tariffs and increasing climate scrutiny, having a domestic removals sector is not a climate-friendly luxury, but an investment in industry and a hedge against trade friction.

There is also a more fundamental argument: carbon risk management. Policymakers already know that delivery of emissions targets can slip, technologies can underperform and politics can cause commitment to waver. While ensuring that removal options don't provide a rationale to slow down gross emissions reductions, developing a portfolio of removal options offers insurance against contingencies, providing a buffer if real emissions cuts falter. Investing now avoids the trap of scrambling in the 2040s, when the bill for negative emissions may rapidly accumulate, becoming far larger and more politically painful. Alongside the climate-responsibility argument, the sharper case for CDR is one of practicality: industrial resilience, economic positioning and strategic insurance.

The Shift From Resistance to Pragmatic Acceptance

Many individuals working in climate policy have rightly held a commitment to focusing on reducing emissions, to avoid the moral and strategic hazard of prioritising removals too early in the decarbonisation journey. That caution shaped policy approaches until recently.

But the journey to reducing global emissions has already been too slow, with some studies suggesting that the world temperature averages have temporarily surpassed, or are about to surpass, 1.5 degrees Celsius of average warming compared to pre-industrial levels.^{3,4,5}

While carbon removals have already captured the imaginations of technooptimists and some political leaders, they are also increasingly becoming a priority for more traditional climate advocates. Christiana Figueres, the executive secretary of the United Nations Framework Convention on Climate Change (UNFCCC) from 2010 to 2016, who led and brokered the Paris Agreement, recently shared:

"Twenty years ago, I was absolutely against even entertaining the idea [of carbon removals] ... because my feeling was that if we opened that door, we would become lazy and we would find all kinds of technical excuses to not do the emission reduction efforts that we needed to. ... [But] We're at the point where we are already not just playing with breaching 1.5, but actually have already breached it. ... Yes, we have to continue to put mitigation and adaptation front and centre, and we also have to start thinking constructively ... What happens if we don't?"



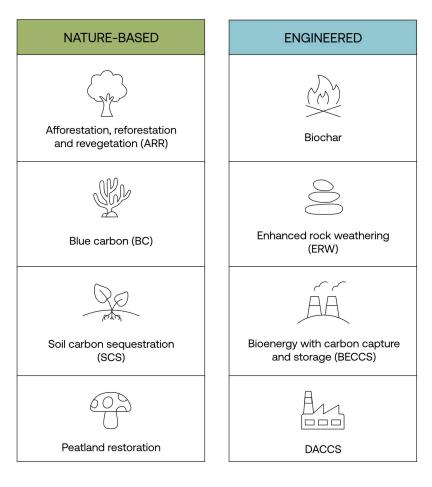
What Are CDR Solutions?

CDR solutions are technologies and practices that remove CO₂ from the atmosphere. They are typically split into two broad groupings: nature-based (often known as "conventional") solutions, which store CO₂ in soils or different kinds of biomass, and engineered (or "novel") solutions, which use technological processes to convert CO₂ into stable minerals, or capture and store it underground in geological formations, depleted gas fields and saline aquifers.^{7,8}

Nature-based solutions make up most of the world's removals capacity today (around 99.9 per cent), at almost 2GtCO₂ per year; ⁹ this is approximately the same as Russia's annual emissions in 2023, and double Japan's emissions – the fourth- and fifth-biggest emitters globally. ¹⁰ According to the United Nations Environment Programme (UNEP), if all potential nature-based solutions – those currently in use plus those yet to be actioned – were implemented across all ecosystems worldwide, they could deliver emissions reductions and removals of approximately 10Gt of CO₂ equivalent (GtCO₂e) per year by 2050, based on a conservative estimate. ¹¹ In contrast, engineered CDR currently accounts for only 0.0013GtCO₂ per year. Going forward, the world will need to significantly scale engineered solutions in addition to nature-based removals. According to the IPCC's pathways, by 2050, engineered CDR must scale to 1.6-4.6GtCO₂/year. ¹²

FIGURE 2

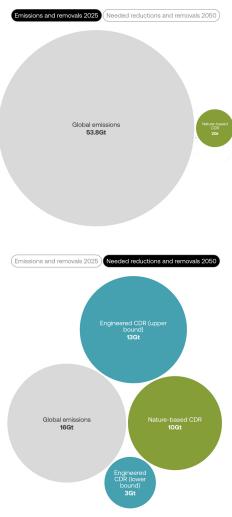
Main types of CDR solutions



Source: TBI

FIGURE 3

Global emissions versus CDR in GtCO₂/ year to limit warming to 2 degrees (present day versus 2050)



 $Source: \underline{University\ of\ Oxford};\ \underline{Emissions\ Database\ for\ Global\ Atmospheric\ Research}$

THE ROLE OF NATURE-BASED SOLUTIONS

Nature-based solutions restore ecosystems, such as forests, wetlands and coastal habitats, to absorb CO_2 into biomass such as trees, roots and soils. Key approaches include afforestation, reforestation and revegetation (ARR), blue carbon (capturing CO_2 in mangroves, salt marshes and sea grasses), soil carbon sequestration and peatland restoration.

Participating in the carbon removals market is a key mechanism for financing nature, complementing other solutions such as Brazil's tropical forest financing facility (the TFFF) which aims to generate financing for forest preservation and protection.

FIGURE 4

Nature-based CDR

	ARR	Blue carbon	Soil carbon sequestration	Peatland restoration
Description	Planting or regrowing trees and vegetation on non- forested or degraded land	Protecting and restoring coastal ecosystems (mangroves, sait marshes, seagrasses) that capture CO ₂ in biomass and sediment	Using land and farm practices (e.g. cover crops, reduced tillage, improved grazing) to increase stocks of soil carbon	Rewetting and rehabilitating drained or degraded peatlands to halt high CO ₂ emissions and restart long-term peat carbon accumulation
Limitations	Land-use trade-offs, risk of reversal, slow carbon accumulation	Limited spatial potential, risk of reversal, site-specific effectiveness, costly MRV, land-tenure conflict, vulnerability to sea-level rise	Reversibility and permanence risks, costly MRV, variable outcomes based on soil type, climate and crop system	Unless managed and allowed to accumulate, peat risks becoming a carbon source; slow peat formation, complex land-management needs, conflict with other land use, costly MRV
Co-benefits	Biodiversity enhancement, water-cycle regulation, local and rural development, climate adaptation and resilience benefits	Biodiversity enhancement, coastal protection, water- quality improvements, economic opportunities through fisheries and tourism	Improved soil fertility and structure, reduced erosion and run-off, reduced fertiliser need, improved income for farmers via carbon-credit revenue	Improved water purification, habitat restoration, flood reduction, fire-risk reduction
Approximate market price (per tonne sequestered)	\$10-40	\$25-250	\$25-30	\$15-40
Durability	25–100 years, with high reversal risk	30–100 years, with reversal risk	Highly variable depending on soil type, depth, climate and management practices, but typically <50 years	Difficult to generalise due to site conditions, management and disturbance risks, but typically <100 years
Market	Mature, with hundreds of millions of credits issued and retired	Still boutique, forming less than 1% of the voluntary carbon market	Still nascent, often bundled with broader "agriculture" or REDD+ categories	Niche, constrained by peatland ecology limits and complex hydrology
TRL	9	Unspecified	8	9
Current removal levels (CO ₂ /year)	1.9Gt	0.24-0.45Gt	Difficult to quantify; estimated <0.17Gt	0.37Gt
Removal potential by 2050 (CO ₂ /year)	0.5-3.6Gt	0.4-1.2Gt	2-5Gt	0.75-1Gt

Source: Sylvera; npj Ocean Sustainability; Storegga; Forestry Commission; CO2RE; Wageningen University & Research; Marine Conservation Society; IUCN; Kleinman Center for Energy Policy; Environmental Research Letters; McKinsey; American University; Project Drawdown; Pongratz et al; Henderson et al. For data on carbon-credit prices: McKinsey, BCG

Note 1: Technology readiness levels (TRLs) are a standardised framework used to assess how close a technology is to full-scale deployment. The scale ranges from TRL 1 (basic research and concept development) to TRL 9 (proven, commercial application). This scale helps funders, policymakers and investors understand the technical maturity and risks of investing indifferent technologies. The TRLs shown here are UK-specific but give an indication of the readiness of nature-based solutions more widely.

Note 2: Current removal levels refer here to total nature-based removals globally, not all sequestration (i.e. Afforestation, Reforestation, and Revegetation levels, not including all forestry-related sequestration).

The market price of nature-based removals is typically lower than for engineered CDR solutions, averaging \$10 to \$40 per tonne of CO₂ sequestered versus \$200 to \$600 for engineered CDR. A Nature-based solutions can also bring benefits for biodiversity, water and soil quality, and provide livelihood opportunities and coastal protection for rural and indigenous communities. For instance, restoring forests and wetlands could

improve habitats for almost 60 per cent of global terrestrial biodiversity, while forested watersheds and wetlands supply 75 per cent of the world's accessible fresh water. 15,16

Nature-based solutions also support climate adaptation and resilience. For example, mangroves, salt marshes and sea grasses can reduce wave energy, stabilise sediments and protect against storm surges. Without global mangrove coverage, for instance, 15 million more people would experience annual flooding.

However, nature-based solutions face several key limitations, meaning that they cannot be depended upon alone for future global removals. Nature-based removals can require significant areas of land, limiting the availability of land for other uses. A report by NASA found that planting half a trillion trees could cumulatively capture 205GtCO₂, enough to negate about 20 years of human-produced carbon emissions. However, this would take up approximately 900 million hectares of land, an area roughly the size of the United States. To be a "permanent" removal, the land used for nature-based solutions such as forestry would need to be 'locked up' forever, limiting future development. This means the land can never be used for housing or agriculture, for example. Furthermore, trees also have finite storage capacity, as their ability to sequester carbon diminishes over their lifecycle.

Finally, nature-based solutions are not as durable as engineered solutions. Carbon stored in biomass is vulnerable to reversal through natural decay, land-use change or environmental disasters such as flooding, forest fires, or damage from invasive species, which are only likely to increase in scale and severity as climate change continues.

Furthermore, the durability of their storage, even without reversal, is not equivalent to the length of time CO₂ remains in the atmosphere: for example, some of the fast-growing trees commonly used for "carbon farming" may only continue to sequester carbon for an average of 28 years, while CO₂ remains in the atmosphere, contributing to warming, for more than a

thousand years. As such, unless the trees are continually replanted in perpetuity, there is a temporal mismatch between the life cycle of this nature-based solution and the emissions it offsets.²¹

Despite these challenges, nature-based solutions are currently the only easily scaled approach that can provide near-term carbon removal. As such, they remain a key tool with which to address warming. If scaled, nature-based solutions could sequester approximately 10 gigatonnes of CO₂ annually by 2050, based on conservative estimates.²²

Establishing a national framework to protect and restore all coastal wetlands in Costa Rica

Costa Rica's National Blue Carbon Strategy²³ is a first-of-its-kind national policy launched in 2023, with an Action Plan initiated in 2024, to integrate the conservation, restoration and management of mangroves, seagrasses and other coastal wetlands into climate policy and coastal governance.

Anchored in the National Wetlands Policy (2017–2030) and the 2020 Nationally Determined Contribution (NDC)'s new "Ocean and Water Resources" pillar, the framework translates Costa Rica's NDC pledges – most notably protecting 100 per cent of inventoried coastal wetlands and expanding estuarine wetland area by 10 per cent by 2030 – into five strategic objectives. These objectives contain concrete actions, indicators and timelines supported by a workstream of legal review, stakeholder mapping, data/MRV aligned with the Norms of Global Governance Initiative and community engagement.

Implementation is led by Costa Rica's National System of Conservation Areas through its National Wetlands Program, coordinated across government by the Ministry for Environment and Energy and the Marine Governance Commission.

THE ROLE OF ENGINEERED SOLUTIONS

Engineered CDR solutions refer to emerging technologies that capture and durably store, or mineralise, CO₂. Their approach varies from utilising carbon storage in biomass and rocks (biochar and enhanced rock weathering) to technologies that directly capture CO₂ from the atmosphere (direct air

carbon capture and storage, or DACCS). Despite their promise, engineered CDR solutions currently account for a tiny fraction of CDR deployment: just 0.0013GtCO₂/year.²⁴ Biochar accounts for the majority of this removal today.

FIGURE 5

Engineered CDR

	Biochar	Enhanced rock weathering	BECCS	DACCS
Description	Converting biomass into a stable, charcoal-like material via controlled, non-emitting burning (pyrolysis) and applying it to soils for durable carbon storage	Spreading finely ground rock on land to accelerate natural weathering, which captures atmospheric CO ₂ and converts it into dissolved carbonates	Generating energy from biomass while capturing and geologically storing the resulting CO ₂ to achieve net removals	Industrial systems that extract CO_2 directly from ambient air and permanently store it, usually underground
Limitations	Variability in permanence, complexity of MRV, limited scalability, cost-effectiveness is context-dependent, potential for environmental harm	Complexity of MRV, uncertainties regarding ecological impact, heavy logistics burden, high energy use in grinding and transport	Very high energy demand, high cost per tonne removed, requires access to low-carbon energy, no ecosystem co- benefits, slow deployment and scale	Very high energy demand, high cost per tonne removed, requires access to low-carbon energy, no ecosystem co- benefits, slow deployment and scale
Co-benefits	Soil-health improvement, waste utilisation, pollution reduction, enables farmers as biochar sellers	Soil remineralisation, use of mining byproducts, better agricultural yield	Renewable-energy generation, waste-to-energy utilisation, offers energy-system reliability	Industrial innovation and job creation, minimal land footprint, use of existing extraction infrastructure
Approximate market price per tonne sequestered	\$100-200	\$70-500	\$60-270	\$500-1,000
Durability	More than 100 years	More than 1,000 years	More than 10,000 years	More than 10,000 years
Market	More than 3 million biochar credits contracted between 2022 and 2025	Nascent but growing, with current agreements only in the 100,000s of tonnes	Very nascent, many projects still in the pre-purchase stage	Very nascent, with less than 2 million credits transacted to date
TRL	9	4–5	6–7	6 (liquid), 7 (solid)
Current removal levels (CO ₂ /year)	~0.79Mt	~0.03Mt	~0.51Mt	0.004Mt
Removal potential by 2050 (CO ₂ /year)	0.5-2Gt	2-4Gt	0.5-5Gt	0.5-5Gt

Note: Technology readiness levels (TRLs) are a standardised framework used to assess how close a technology is to full-scale deployment. The scale ranges from TRL 1 (basic research and concept development) to TRL 9 (proven, commercial application). This scale helps funders, policymakers and investors understand the technical maturity and risks of investing in different technologies.

Source: TBI; $\underline{\text{Green Finance Institute}}$; $\underline{\text{Puro.earth}}$; $\underline{\text{CO}_2\text{RE}}$; $\underline{\text{CRD.fyi}}$; $\underline{\text{University of Oxford}}$; $\underline{\text{IEA}}$; $\underline{\text{Environmental Research Letters}}$. For data on carbon-credit prices: $\underline{\text{Carbon Credits}}$, $\underline{\text{FT}}$, $\underline{\text{McKinsey}}$

Unlike nature-based solutions, engineered removal solutions offer high durability, dissolving CO₂ into stable minerals or storing it in deep geological formations for centuries to millennia, with minimal leakage risk. This durability is important because in order to stabilise global temperatures, carbon emissions need to be permanently stored without risk of being released back into the atmosphere.

However, there are challenges to scaling engineered CDR solutions. These solutions remain significantly more expensive than either nature-based alternatives or prevailing carbon prices on emission-trading schemes. Bioenergy with carbon capture and storage (BECCS) and DACCS are currently particularly costly, in the region of \$200 to \$600 per tonne of CO₂. Without strong policy support to enable learning by doing and economies of scale, among other drivers of cost reductions, early market demand tends to favour cheaper – and less durable – alternatives. ²⁵

Engineered CDR solutions also require large inputs of energy, water, biomass and/or chemicals. DACCS is heat- and electricity-intensive, with efficiency and cost depending heavily on access to reliable base-load renewable energy (such as geothermal or hydropower) which is typically less available than solar and wind. BECCS is constrained by rising biomass costs – particularly for wood pellets – which may require significant land expansion, raising land-use conflicts and sustainability concerns.

THE NEED FOR A DIVERSE PORTFOLIO OF REMOVAL METHODS

A diverse portfolio of solutions is essential for the world to achieve the scale and permanence of carbon removal required to limit temperature rises. Nature-based solutions offer the lowest-cost and most scalable solutions today. However, the overall contribution of these solutions is limited by global land availability, slower carbon uptake and vulnerability to reversal from fire, pests or land-use change. As such, while these approaches remain crucial in the near term, alone they cannot deliver the multi-gigatonnes of annual removals needed without threatening biodiversity, food security or social priorities.

In contrast, engineered removals, particularly BECCS and DACCS, are costlier and less mature today. However, engineered CDR solutions promise high durability and the opportunity to sequester large volumes of CO₂ in the longer term.

Together, this points to the need for a dual approach: deploying mature, nature-based removals now to generate near-term impact, while investing in less mature, higher-durability engineered options that will deliver scale and durability going forward.



Scaling Removals Presents an Opportunity for Every Country

At the highest level, scaling removals is necessary to keep global temperature rises in check. But CDR also presents an economic and strategic opportunity for individual nations.

Although it is necessary to scale a diverse portfolio of removal solutions, countries won't all play the same role: comparative advantages are decided by geology, land and biomass, energy costs, and policy capacity. Some countries will be better equipped to shape demand through public procurement, compliance rules and standards, while others will drive supply and monetise nature-based carbon sinks based on their natural assets.

Countries with a history of low emissions often have higher nature-based carbon-sequestration potential than those who have historically emitted more. There is an opportunity for these countries to capitalise on this potential to attract finance for removals projects. For example, natural-resource-rich low- and middle-income countries (LMICs) can harness those resources to leverage climate finance to scale removals while delivering development gains. Biochar is a good example: in addition to locking carbon into stable forms for decades, if not centuries, converting crop and forestry residues into biochar also can increase the nutrient-use efficiency of soils, and can raise smallholder yields and food security. Residues into biochar also can food security.

On the other hand, a country like the UK could capture domestic economic benefits from scaling CDR. One report notes that deployment of greenhouse-gas removal in the UK could support up to 60,000 jobs by 2050, both through domestic project development and the export of technologies and services (based on delivery of 35.8 million tonnes of engineered removals by mid-century).²⁹

To showcase the opportunities for different nations, this paper uses the high-level country archetypes shown in Figure 6. The archetypes are designed to be illustrative, and a single country could sit within more than one archetype. These archetypes are also used to explain where recommendations in the final section of this paper are most relevant.

FIGURE 6

Country archetypes and opportunities in CDR markets

Archetype	Description	Opportunities to be gained from scaling CDR
High-income industrialised countries e.g. UK, Germany, Canada	These economies generally have capital, strong institutions and historically strong records on climate.	Harnessing technological innovation Driving jobs in regions Asserting climate leadership
Land-rich lower- and middle- income countries e.g. Brazil, Indonesia	These economies generally have biomass, land and restoration potential, but weaker finance and governance capacity.	Boosting food security by prioritising removals that car improve soil quality and boost yields Increasing biodiversity to support climate resilience Boosting finance and jobs in rural areas
Fossil-fuel-rich exporters e.g. Norway, Saudi Arabia, Qatar	Fossil-fuel extraction plays a major role in these economies.	Diversifying economies by repurposing oil and gas capabilities to permanently store carbon, protecting jobs and creating exportable services Harnessing energy-intensive CDR to generate high-integrify removal credits and diversify revenue Selling storage-as-as-ervice – e.g. to opening ports to import and permanently store CO ₂
Technology and policy pioneers e.g. Singapore, South Korea, Switzerland	Land-constrained but capital-rich countries with strong climate ambition for imported removals. These countries can experiment with innovative instruments.	Leading on certification, MRV and registries, and exporting verification, data and auditing services Bullding innovation hubs in key technologies like mineralisation, monitoring tech and finance tools
Vulnerable low-emitting countries e.g. Seychelles, Belize, Bahamas	Highly climate-vulnerable, often with negligible emissions. These countries can act as hosts for smaller-scale removals.	Monetising blue and nature-based sinks with resilience co-benefits – e.g. mangroves, seagrass and peatlands 2. Growing a "blue economy" jobs pipeline, creating livelihoods in restoration and eco-tourism

Source: TBI



Building and Regulating Markets for Removals

Some countries are already aware of the economic opportunities that scaling carbon removals offers and are taking steps to realise them. For example, the UK has acknowledged both its need for removals to meet its net-zero targets (the Climate Change Committee says the UK needs around 58MtCO₂/year of engineered removals and 39MtCO₂/year from land sinks by 2050), as well as announcing several policy initiatives to get there, including integrating removals into its Emissions Trading Scheme (ETS). Meanwhile the EU has adopted the Carbon Removal and Carbon Farming (CRCF) Regulation, a rulebook to certify permanent removals and carbon-negative farming activities, which will enable their future use in policies and markets.

Denmark has indicated that it aims to become a carbon-storage hub, offering part of its storage capacity to other European countries to store their CO₂. The government is also encouraging market development by agreeing to buy 1.1 million tonnes of durable carbon removal from companies.³⁰ Similarly, Indonesia is progressing its plans to become a regional hub for "carbon-storage services" for South-East Asia, including progressing regulations to allow storage for imported CO₂.³¹ Kenya too is utilising its abundant renewable energy and basalt deposits, to create a hub for carbon storage and management.³²

Other countries are implementing policies to scale nature-based removals. For example, Costa Rica is implementing blue-carbon restoration at a national scale, while Kenya has set out national carbon-market rules to establish project registration, benefit-sharing and a national registry, all of which are key to attracting finance.

Closing the Removals Gap

There is still a huge gap between the amount of carbon being removed today, and the level of investment and policy support needed in both the near and longer-term to limit temperature rises. For example, while

engineered CDR capacity has increased from 0.66MtCO₂/year in 2021 to 1.35MtCO₂/year in 2023, according to the IPCC, engineered CDR solutions will need to scale to 1.6-4.6GtCO₂/year by 2050, from 0.0013Gt in 2025.³³ While the latest *State of CDR* assessment indicates that momentum on CDR has increased, policies to scale the technologies remain patchy.³⁴

The fundamental barrier to scaling removals is that they don't currently have a natural market. Carbon removals generate a global public good (given that a tonne of CO₂ removed from the atmosphere benefits everyone) but there isn't an automatic buyer for "negative emissions", therefore it is not immediately clear who should, and will, pay for them. Without clear, durable demand signals, investment and supply will remain constrained.

To date, demand has come predominantly from a small group of voluntary corporate buyers, with some early public procurement. For example, Microsoft has a formal carbon-removal programme and multi-year offtakes, including 10,000 tCO₂ from DACCS specialist Climeworks over ten years. Microsoft accounts for 80 per cent of the total credits purchased from carbon-removal projects. Separately, Stripe Climate's Frontier is a joint advance market commitment (AMC) with partners like Alphabet, Shopify, Meta and McKinsey to purchase an initial billion dollars' worth of permanent carbon removal by 2030. These companies are acting for practical and strategic reasons: to meet their own climate targets and manage hard-to-abate residual emissions; to secure scarce high-integrity supply early; to prepare for future compliance or customer requirements; and to demonstrate leadership to investors, clients and employees.

Exomad Green

Bolivia's Exomad Green has built an industrial-scale biochar CDR platform by converting hardwood-forestry residues into high-carbon biochar at two pyrolysis plants certified under the Puro.earth biochar methodology. As of 2024, the company reports ~120,000 tCO₂/yr of removals from these sites and is planning five facilities targeting ~1 MtCO₂/yr by 2027. The biochar produced is consistent with long-lived storage under the Puro Standard – a voluntary market standard for removals.

Exomad Green is also scaling up via corporate agreements: Microsoft has contracted an initial 32,000 tonnes for delivery by June 2024, and in May 2025 agreed a ten-year, 1.24Mt biochar-removal offtake agreement, the largest-ever biochar deal to date. At the same time, Swiss Re signed a separate seven-year, 70,000-tonne biochar offtake sourced from Exomad's Riberalta project. Independent market tallies show Exomad leading 2025's durable CDR deliveries with approximately 203,000 tonnes, underscoring biochar's role as today's largest source of durable removals.

However, voluntary action alone cannot close the gap. Corporate demand is still too small and concentrated, and investment will not scale without clearer, more durable demand signals. Governments and regulators therefore need to convert today's pilots into predictable, investable pipelines that will develop into a self-sustaining market. In addition, carbon removal needs to be accessible at a price society is willing to pay. This results in a catch-22 situation: high prices deter demand for engineered solutions, but

the lack of clear sustained demand disincentivises investment in the innovation that could bring costs down. Without much broader demand, projects won't reach the volumes needed for cost declines.

Figure 7 sets out the principal barriers to scaling carbon removals, with several cutting across both engineered and nature-based removals.

FIGURE 7

The barriers to scaling carbon removals

BARRIER TYPE	CDR TYPE
Both demand- and supply- side	All
Supply-side	Primarily NbS
Demand-side	Primarily engineered
Supply-side	All
Demand-side	All
	Both demand- and supply-side Supply-side Demand-side Supply-side Supply-side Supply-side Supply-side

Source: TBI

These barriers are solvable. The next section sets out interventions that can help address these barriers.



Recommendations

Governments can turn carbon removals from niche pilots into credible, large-scale markets by acting on four interconnected pillars: establishing integrity, building demand and finance, planning strategically, and empowering participation. Together, these actions create the trust, capital and coordination needed for removals to complement deep emissions cuts and strengthen national net-zero pathways.

Pillar 1: Establish standards and integrity. For governments, writing carbon-removal rules is both a technical task and a way to shape who leads the market. A clear, unified government-backed integrity standard would make removals investable, protect domestic firms from reputational risk and give regulators a lever in global markets. When a government defines what counts as a tonne of CO₂ removed, that government sets the benchmark others must meet. Digital MRV, permanence tiers and interoperable registries aren't bureaucratic overreach but industry infrastructure: they build credibility, keep low-quality projects out and make every verified tonne an exportable commodity. Countries that move first will shape the rules, and hold the revenue streams, of the future removals market.

Pillar 2: Build market demand and finance. Markets need financial and policy certainty more than rhetoric about climate ambition. Governments that create reliable demand for removals will capture the investment, innovation, jobs and profits that follow. Integrating removals into compliance markets or establishing a purchasing authority will anchor long-term price signals and build a domestic customer base. Public AMCs, backed by guarantees and performance insurance, can de-risk early projects without significant fiscal cost, while green and blended finance reform will draw in private capital. The political benefit is significant: industrial advantage in new technologies and visible control over an emerging market that would otherwise grow elsewhere.

Pillar 3: Plan strategically and integrate nationally. Linking land use, agriculture, energy systems, storage infrastructure and planning portals turns climate ambition into economic coordination. Governments that map

sites, integrate permits and develop shared CO₂ storage networks cut project delays and attract investment. The real prize is not only emission removals but new and more secure jobs in engineering, forestry and farming.

Pillar 4: Empower small players and communities to participate in carbon removals. Carbon removals will only scale if the people who manage the land share in the gains. Aggregation platforms, technical assistance and regional hubs turn smallholder projects into credible, investable portfolios. Digitalised land rights and community profit-sharing make contracts enforceable and benefits visible – which is vital for political durability. These measures lower MRV costs, strengthen data quality and build social legitimacy, which converts into stable projects, rural income and citizens who see the transition as profitable – for nature and their wallets.

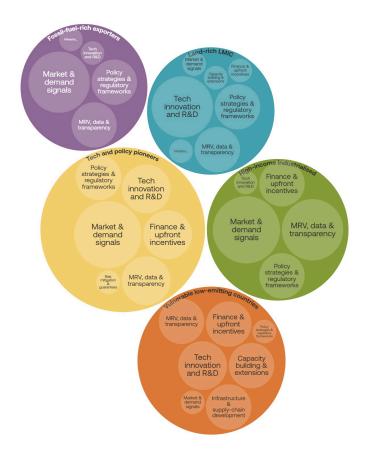
Outcome: A trusted, inclusive and scalable CDR market. Acting across these four steps will build the integrity, investment and inclusion needed for carbon removals to scale responsibly, turning them into a lasting pillar of global climate action and a source of new economic opportunity.

The Tony Blair Institute for Global Change (TBI) has built a CDR policy data set that systematically evaluates the opportunities and risks of each CDR policy, their relevance to each country archetype, and their financial and political feasibility.³⁷ The policy packages are presented in Figure 8.³⁸ The methodology summary can be found in the appendix.

FIGURE 8

TBI's CDR-policy data set

Select a circle to reveal its themes, and click again to dive deeper into related policies



Source: TBI

Pillar 1: Establish Standards and Integrity

Establishing standards and integrity is the foundation for credible carbonremoval markets. Governments must define what counts as a tonne removed, align standards internationally and ensure transparent, verifiable monitoring, including the process if removal stores fail. These steps create the trust, comparability and data infrastructure needed for carbon removals to scale with integrity.

RECOMMENDATION	ARCHETYPE	оитсоме
Define and certify removals, and harmonise them internationally	All country types	Tackles the lack of agreed standards

Carbon removals need a single, consistent definition for what "counts" as a real tonne removed, and how that is verified and monitored over time.

The lack of an agreed global standard risks creating a fragmented market with incompatible systems, confusing investors and purchasers and adding complexity for project developers and suppliers. A coalition of early movers should align their government-backed standards quickly, forming a single set of definitions that is universally used. This coalition is likely to be led by those already creating demand and, if they leverage purchasing to define the standards first, together they will in effect define the standards for the future. Governments should therefore back this aligned framework with tiered permanence rules, rigorous MRV processes and interoperable registries. This will help to make the removals market investable, avoid fragmentation, and position early adopters and collaborative leaders at the forefront of a global CDR market.

To operationalise this all-solutions approach, policymakers should establish dual permanence tiers for CDR technologies.

FIGURE 9

Dual permanence tiers for CDR technologies

	Tier 1: Short- to medium-term removals	Tier 2: Long-term removals
Durability	200 years	200+ years
Removal solutions	ARR, soil carbon sequestration, blue carbon, peatland restoration	Enhanced rock weathering, biochar, DACCS, BECCS
Definition	These methods are low-cost, immediately scalable, and provide co-benefits for ecosystems and communities. They should be incentivised for their near-term mitigation and adaptation value, while subject to robust monitoring and buffer mechanisms to manage reversal risks.	These should form the backbone of long-term net-negative strategies and be prioritised for research, infrastructure investment, and integration into compliance markets/long-term procurement strategies.

Source: TBI

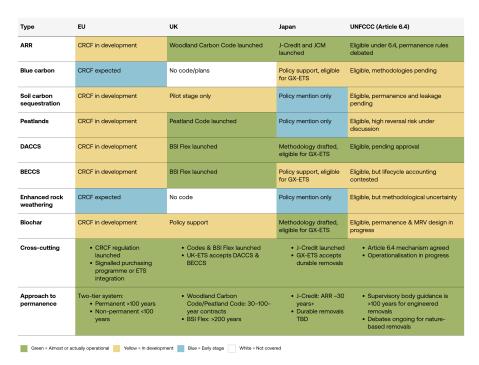
By distinguishing between durability tiers, governments and markets can reward both immediacy and durability, ensuring rapid climate progress without sacrificing long-term integrity. This framework would also create clearer price signals, allowing investors and credit buyers to align portfolios with specific climate objectives and durability preferences.

The EU, UK and Japan are currently leading the development of government-backed methodologies and standards, with the UN Article 6 methodology-review process also underway. They each have varying degrees of coverage and have differing priorities for different removal types. For example, the EU's CRCF Regulation certifies three categories of removal activity: permanent removals, carbon farming and carbon storage in products, with each category generating distinct carbon credits that can be counted towards the EU's NDC. Similarly, the UK has advanced its Greenhouse Gas Removals (GGR) Business Model, with the British Standards Institution (BSI) developing interim DACCS and BECCS standards to underpin early projects. Japan's GX-ETS and J-Credit system have also begun to recognise durable removals, while the UNFCCC is finalising eligibility under Article 6.4.

Countries will prioritise different CDR options, so coverage will vary. Most frameworks include both nature-based and engineered removals and use tiered permanence definitions. For the removals market to scale, more governments need to codify these methodologies and align them internationally.

FIGURE 10

Current state of regulatory removal standards and methodologies



 $Source: \underline{EU\ CRCF},\ BSI\ \underline{BECCS}\ \&\ \underline{DACCS};\ \underline{Woodland\ Carbon\ Code}; \underline{Peatland\ Code}; \underline{Japan\ GX-ETS}; \underline{UN\ Article\ 6.4}$

Implementation should be plurilateral. A group of early-mover governments, likely including the UK, EU, Japan and others that have made substantial standard-setting progress so far, should align their rules to ensure progress towards a single global standard. Their definitions of additionality, leakage, monitoring, reversals and permanence tiers need to be aligned as a core foundation, to demonstrate that a tonne removed in one country is

equivalent in another. Such alignment and mutual recognition would create clarity for markets, credibility for governments and allow each nation to use those methodologies for their own schemes, such as tax credits, carbon-tax compliance units or corporate-claims rules.

To strengthen this alignment, and prevent potential future fragmentation, these aligned standards should be cemented through the ISO process, ensuring that other countries, too, use the same rules going forward.

For leaders, the aim is clear: by speaking a common technical language, they can turn scattered national efforts into a trusted international market, showing citizens around the world that carbon removals are being done properly.

RECOMMENDATION	ARCHETYPE	ОИТСОМЕ
Build out digital MRV infrastructure and harness satellite technology	All country types	Provides enabling infrastructure

Integrity also depends on credible MRV together with transparency over the ownership of credits. Digital MRV infrastructure should be treated as national climate infrastructure. Governments have an interest in ensuring interoperable MRV systems and may need to build them where private sector isn't providing them. Where MRV is provided by the private sector, the government needs to ensure it is robust and fit for purpose. National registries capable of tracking credits, reversals and retirements, integrating remote sensing, AI and satellite analytics can reduce costs and improve accuracy. These digital systems should connect to international registries and align with Article 6 accounting to ensure fungibility and prevent double counting.

From high-resolution satellite imagery to Al-driven biomass models, digital MRV can underpin how certain carbon-removal solutions are monitored, verified and managed. Integrating these tools into national MRV systems enables real-time alerts on deforestation and land-use change, allowing authorities to protect carbon stocks and strengthen project integrity. The European Space Agency's Copernicus programme already tracks canopy cover and soil moisture across the EU, while platforms like Land & Carbon

Lab and the Food and Agriculture Organization (FAO)'s Open Foris are helping countries in Africa and Latin America embed satellite data directly into greenhouse-gas inventories and carbon registries.

These digital systems can also help track biomass (organic material) across supply chains. Al and satellite imagery can help ensure that materials for projects like biochar or BECCs are sourced sustainably and don't contribute to deforestation or food insecurity. In India, Mati Carbon combines satellite imagery with Al to monitor enhanced rock weathering, while the Kenya Agricultural Carbon Project (KACP) uses digital tools to track soil-carbon gains across thousands of small farms. Embedding data pipelines into national CDR strategies like this lowers MRV costs, builds investor confidence and turns removals into a measurable, accountable part of climate action.

Mati Carbon

Mati Carbon is scaling enhanced rock weathering in India by supplying finely ground basalt to smallholder farms, especially rice paddies, in states such as Chhattisgarh, Madhya Pradesh and Jharkhand, and pairing deployment with a science-led MRV stack developed with the Yale Center for Natural Carbon Capture. In 2023, the Frontier AMC coalition, comprising companies such as Google, Stripe, H&M and Shopify, selected Mati Carbon to facilitate the first global enhanced-rock-weathering deliveries from a project in the Global South. This amounted to some 50 tonnes of durable removals in March 2024, followed by a larger tranche of 420 tonnes later that year, demonstrating measured, credited outcomes rather than projections. ³⁹, ⁴⁰

To accelerate deployment, in May 2025 Mati secured an innovative debt facility, backed by J.P. Morgan with credit support from the Schmidt Family Foundation, and is aiming to form partnerships with 30,000 smallholder farmers across India, Tanzania and Zambia by the end of 2025.⁴¹

Pillar 2: Build Market Demand and Finance

One of the most significant barriers to scaling carbon markets is a lack of clear demand. Creating predictable long-term demand and unlocking affordable finance are essential steps to move carbon removals from pilot to scale. Governments should act to generate credible markets for removals in their own jurisdictions, thus mobilising the capital needed to deliver them. The outcome is likely to be industrial advantage and control of an emerging market.

RECOMMENDATION	ARCHETYPE	OUTCOME
Develop mechanisms to purchase carbon removals	High-income industrialised countries and tech and policy pioneers	Tackles the lack of demand

High-income industrialised countries have been at the forefront of not only climate politics and the development of carbon-pricing instruments like emissions-trading systems and carbon taxes, but also the scaling up of carbon-removal financing. Creating policy-backed markets that govern the commodity of removals is central to the toolkit. Two examples of leading purchase mechanisms are integrating removals into existing compliance carbon markets (ETSs or carbon taxes), or a carbon-removal authority.

FIGURE 11

Leading CDR purchase mechanisms

Compliance-market integration (CMI)

CMI would allow companies to (or ETS) liability with removal units,

thus redirecting 5 per cent of those government revenues directly to the

financing of CDR credits.

Source: TBI

Carbon-removal authority (CRA)

A CRA would act as a direct public purchaser of CDR, buying replace ~5 per cent of their carbon tax units on behalf of the government. This structure would bring price and quantity stability, clear liability rules, and economies of scale as government negotiates pricing, but requires new institutions and legislation.

The political dynamics surrounding these two options are complex. While CMI might represent a politically easier technical adjustment to an existing system and follow a "polluter pays" narrative, a CRA - if accompanied by the appropriate framing, emphasising accountability, collaboration and financial efficacy - could deliver greater political legitimacy.

The UK announced in mid-2025 that it would integrate removals into the UK ETS with a 5 per cent cap (CMI), with actual operationalisation due by the end of 2029. ⁴² Japan is also taking this approach, whereas the EU is currently exploring a CRA for short-term removals purchases (between 2025 and 2030). ⁴³

However, while enabling emitters to use removals to meet compliance-market obligations should support market development, this alone will not provide the certainty of demand needed for investment. Even with removals as an option, there is no guarantee that companies would take the opportunity to use these solutions. As such, policymakers should consider requiring entities with an obligation under an ETS to initially meet a very small fraction of their obligation (for example 0.5 per cent) through durable removals. This would ensure, rather than simply enable, purchases, and result in a regulatory framework that would provide certainty of demand for engineered solutions.

Modelling the potential economic and long-term impacts of these options shows that a centralised CRA is more likely to gain economies of scale, with an authority able to purchase entire projects, while CMI integration is the most practical in providing financing for removals at or close to the ETS price.

FIGURE 12

Cost variables in different CDR purchase mechanisms

Metric	СМІ	CRA
Mean cost level	Close to ETS price, with modest savings (≤5%)	~10% below storage cost (economies of scale)
Cost distribution	Emitters pay, with government forgoing modest (≤10%) potential CMI tax revenue	Government, unless hypothecated
Price volatility	High (driven by ETS swings, limited smoothing)	Low (authority smooths cycles)
Investor certainty	Moderate (small, capped niche)	High (long-term contracts)
Political optics	Technocratic, less visible, low displacement risk with cap	Bureaucratic but shields consumers, higher fiscal burden
Systemic effect	Efficiency gains but weak signal for removals	Long-term stewardship and stability

Source: TBI analysis

Both models are mutually reinforcing: CMI can mobilise private actors and integrate removals into existing compliance systems, while a CRA could provide the centralised, stable demand and transparency needed to scale investment and reduce cost. Together, they form the policy and demand-side backbone for durable, high-integrity carbon-removal markets. Governments should consider these based on their respective fiscal, administrative and political contexts.

The carbon-takeback obligation: an innovative alternative?

The carbon-takeback obligation (CTBO) is a form of net-zero regulation that provides an alternative (or complement) to either compliance-market integration or a carbon-removal authority. It requires fossil-fuel producers and importers to permanently store a progressively increasing share of the carbon content of their products. It operationalises the "polluter pays" principle, an approach that enjoys consistently high levels of public support across major economies. By targeting producers rather than consumers, the CTBO creates visible accountability and a direct incentive for fossil-fuel companies to invest in carbon-storage infrastructure. Because the obligation scales gradually, pricing is expected to track underlying storage costs as firms compete to drive efficiencies and expand capacity.

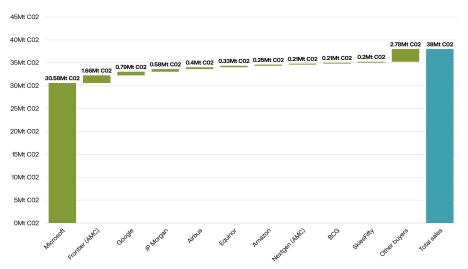
Modelling suggests that in the long term, a fully phased-in CTBO could result in retail-price increases of around £0.50/\$0.66 per litre of petrol to achieve net zero, though this would occur gradually over decades, and displace ETS costs as it was phased in. This approach offers powerful political narratives, clear environmental logic and social fairness, but its near-term consumer impacts and infrastructure dependencies mean that any scale-up of a CTBO should start small (alongside other market and government mechanisms) and be implemented in such a way that it only starts to have a greater impact on consumer costs once households are less exposed to fossil-fuel prices at the fuel pump or in heating bills. Starting the obligation at initially a very low percentage of emissions produced would address this consumer exposure in the near term.

RECOMMENDATION	ARCHETYPE	OUTCOME
Support and build collaborative AMCs	High-income industrialised countries and tech and policy pioneers	Tackles the lack of demand and policy volatility

AMCs from large corporates thus far represent the single largest buyers of CDR around the world. Microsoft set the benchmark with its multi-year, billion-dollar offtake agreements. Frontier, backed by Stripe, Google, Meta and other tech giants, has demonstrated aggregated demand through collective procurement, pledging \$1 billion by 2030. The NextGen CDR facility delivers similar results among a more corporate set of members (including Boston Consulting Group, Swiss Re and UBS), committing \$1.6 billion for engineered removals. These efforts show that AMCs work – they bring credibility, channel investment and de-risk innovation. Yet, despite their ambition, private-sector AMCs remain small relative to the scale of CDR demand needed.

FIGURE 13

Top 10 CDR buyers globally, as of September 2025



Source: CDR.fyi

This is where governments like the UK, EU, Japan and other CDR leaders <u>can</u> and <u>must step in</u>. These nations already have binding net-zero targets that spell out an explicit role for CDR, and the institutional machinery to design and implement an AMC: government-backed removals methodologies and auditing mechanisms, demand structures through compliance-market integration like through Japan's GX-ETS, market infrastructure like the UK's GGR Business Model, and explicit roles for CDR, like in each jurisdiction's NDC. Taking the initiative on this would not only demonstrate international leadership but also lock in technological and commercial gains from the removals industry.

If the EU joined Japan and the UK on integrating 5 per cent removals into their respective ETSs, they could produce some 95.4MtCO₂ of annual demand for removals, more than double the 38Mt cumulatively sold of removals today. Furthermore, by linking an AMC to existing compliance carbon markets, this would make removals investable against compliance obligations rather than voluntary pledges alone, while also not increasing government expenditure.

Designing the next generation of AMCs will be crucial to sustaining this momentum. Contracts should be structured to reward scale and cost reduction, not just early participation. Milestone-based payments could provide finance along the way – de-risking construction, MRV setup or first-of-a-kind deployment – but the greatest financing would be awarded to developers who deliver permanent removals at scale and at a specific, verified low cost per tonne.

This approach borrows from successful models in other sectors. The Market Shaping Accelerator at Chicago University is currently exploring options for a CDR AMC that draws on lessons from the pneumococcal-vaccine AMC launched in 2009, which spurred global vaccine manufacturing, and from ongoing green-cement and sustainable-aviation-fuel AMCs designed to accelerate cost curves through competitive incentives. A well-designed CDR AMC should similarly focus on learning by doing, rewarding technological progress and driving the durable-removals market down the price curve, just as early renewable-energy auctions did a decade ago.

By combining the pioneering leadership of the corporate AMCs with the purchasing power and policy reach of governments, leading economies could unlock a removals market worth tens of billions annually at scale and cost efficacy by the 2030s. In doing so, they could provide the world with the "backstop" it needs for net zero while creating new engines of growth and industrial leadership.

RECOMMENDATION	ARCHETYPE	OUTCOME
Mobilise green and blended finance for high-capex removals	High-income industrialised countries and tech and policy pioneers	Tackles insufficient investment and scaling frameworks

Scaling carbon removals requires access to affordable capital, yet most projects face high upfront costs, long payback periods and limited eligibility within existing green-finance systems. Governments could unlock investment by combining blended-finance tools that de-risk early projects with green-taxonomy reforms that open the gates of sustainable capital markets. Together, these steps would mobilise billions in private finance and make carbon removals investable and bankable at scale.

The clean-energy transition has already proven this model. For example, Zambia's Scaling Solar programme used World Bank guarantees to deliver Africa's lowest solar tariffs; ⁴⁶ Kenya's Lake Turkana Wind Power Project relied on African Development Bank (AfDB) risk cover to unlock private debt; ⁴⁷ and the AfDB's partial credit guarantee enabled the financing of the Tiwi-MakBan geothermal complex in the Philippines. ⁴⁸

The same approach could now be applied to CDR. Nature-based examples already exist: the UN's Land Degradation Neutrality Fund and the Global Fund for Coral Reefs combine grant windows with commercial capital to finance restoration and blue-carbon projects. ^{49, 50} But guarantees are most powerful when applied to capital-intensive, engineered removals. New guarantee platforms such as the Green Guarantee Company and Development Guarantee Group are credit-enhancing green bonds, while GuarantCo provides long-tenor local-currency guarantees for sustainable infrastructure. The World Bank and European Bank for Reconstruction and

Development aim to triple guarantee issuance to \$20 billion per year by 2030, with the World Bank now extending coverage to carbon-market transactions. ⁵¹

The core risks that these instruments absorb (namely policy, counterparty and currency risk) are those that deter DACCS, BECCS and biochar investors. CDR therefore needs existing financial providers to recognise it as eligible infrastructure. Updating their mandates to allow CDR access to guarantees and capital markets would allow banks to price removals like established renewables, lowering the cost of capital and crowding in institutional money at scale.

In parallel, green-taxonomy inclusion must ensure that high-integrity removals are recognised within the same financial architecture that powers clean energy. Green taxonomies already shape trillions in global capital: \$1.1 trillion worth of bonds were issued under them in 2024 alone, yet many still only partially recognise CDR solutions. ⁵² Incorporating certified removals into national and regional taxonomies, aligned with government-backed MRV and permanence standards, would unlock access to green-bond and loan markets for CDR developers. This would also extend environmental-safeguard criteria such as "Do no significant harm" to removals, ensuring that only genuine, durable projects qualify.

As seen with wind, solar and later industrial decarbonisation projects, taxonomy recognition will help accelerate cost declines and mainstream investment. Taxonomy recognition brings the cost of capital down and increases access to capital, which in turn will bring down product costs. ^{53,54} Forestry and blue-carbon projects already qualify in some jurisdictions, but the inclusion of capital-intensive technologies like BECCS, DACCS and biochar would catalyse the next wave of green-finance flows. By aligning blended-finance tools with taxonomy reform, governments can move carbon removals from pilot to portfolio: mobilising global capital, crowding in private buyers like Microsoft and positioning CDR as a core pillar of sustainable finance and industrial policy.

The fundamental blocker is product requirements. CDR doesn't need new financing institutions, but rather needs existing guarantee providers and green financiers to accept CDR. In practice that means updating taxonomies and mandate letters so that these providers can provide CDR offtakes, CfDs and green bonds just as they do with power purchase agreements and bond issuance for renewables. Adjust this, and banks can price and finance engineered CDR like established infrastructure, thus lowering the cost of capital and crowding in private money at scale.

Stockholm Exergi BECCS deal with Microsoft

In 2024, Stockholm Exergi and Microsoft signed what was then the world's largest permanent carbon-removal offtake: 3.33Mt over ten years from a BECCS unit at Stockholm's Värtan combined-heat-and-power plant, with deliveries starting in 2028. In May 2025, Microsoft expanded the deal to 500,000 tonnes per year over ten years, with maximum plant capacity allowing the removal of 800,000 tonnes of CO₂ per year. The deal advances BECCS by proving a bankable revenue stack (large, long-term corporate demand layered on top of substantial public support), reducing risk across the value chain and enabling scaling.

In 2025 Stockholm Exergi won the Swedish government's BECCS reverse auction to receive just over £1.6bn of support paid over a period of up to 15 years⁵⁵ within a national scheme valued at up to £2.84bn (between 2026 and 2046). The project is also backed by €180mn from the EU Innovation Fund.⁵⁶ Together, Microsoft's expanded offtake, the Swedish state contract and EU funding de-risk construction and storage contracting, signal quality (through strict MRV and sustainable biomass criteria) and create a replicable blended-finance model for durable removals in district-heating systems.

RECOMMENDATION	ARCHETYPE	OUTCOME
Build government-backed performance insurance for CDR	High-income industrialised countries and tech and policy pioneers	Tackles insufficient investment and pricing volatility

Early buyers of CDR fear under-delivery and reversals. A governmentbacked performance backstop, funded by risk-based premiums and developer reserve contributions, could insure against delivery shortfalls and purchase substitutes when needed. Eligibility should be limited to projects meeting stringent MRV and permanence rules, with co-insurance from private carriers to avoid moral hazard. This would lower developers' cost of capital and raise market confidence.

Such a mechanism would mirror existing government-backed risk-transfer instruments. Project developers would pay risk-adjusted premiums into a fund managed by a government agency. If a project under-delivers, payouts would then be made directly to buyers or fund substitute removals on the market. Governments could then cap coverage levels, require co-insurance from private insurance companies and restrict eligibility to projects that meet stringent MRV standards.

The design should also guard against perverse incentives. Developers could pay into the scheme through reserve contributions, ensuring that public finance complements rather than replaces the private sector's responsibility.

While there is no existing example of such a government-backed scheme for CDR, there are similar examples in other sectors:

- Forest carbon-credit buffer pools: California's carbon-compliance
 market requires forestry projects to contribute to a pooled reserve. If a
 wildfire or pest outbreak reduces carbon stored, the pool compensates
 buyers.
- Crop insurance: The US Department of Agriculture subsidises policies that protect farmers against the impact of drought or pests on crop yields.
- Renewable-energy guarantees: Feed-in tariffs and long-term power purchase agreements in Europe and China remove revenue risk for developers, catalysing the rapid expansion of wind and solar.

A performance-insurance scheme would reduce the cost of capital for developers, increase buyer confidence and accelerate the scaling of engineered CDR methods. By conditioning coverage on rigorous standards, governments could also raise the bar for quality across the market.

RECOMMENDATION	ARCHETYPE	OUTCOME
Build CDR bundles to share costs and financing across CDR types	High-income industrialised countries and tech and policy pioneers	Tackles insufficient investment, high costs and pricing volatility

CDR is indispensable, but markets remain segmented between CDR types, given their variance in pricing, permanence, availability, and commercial and technological readiness. Without intervention, buyers will either gravitate towards the cheapest options (risking poor integrity) or avoid removals altogether until technologies mature and prices come down.

A portfolio approach, which treats CDR like an exchange-traded fund, could offer a solution.

CDR bundles would tackle multiple barriers:

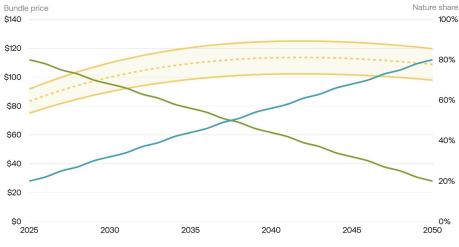
- Scaling supply: Diversification would reduce project-specific risk, creating investable products for institutional buyers and lowering financing costs for developers.
- Spreading resources: Bundles would channel funding across methods, avoiding over-reliance on either cheaper but impermanent removals or prohibitively expensive durable technologies.⁵⁷
- Ensuring permanence: The built-in balance between nature and technology could ensure that long-lived storage grows steadily, while nature-based approaches remain funded for their biodiversity and social co-benefits.⁵⁸
- Reducing costs: By aggregating demand, bundles could accelerate deployment, driving technologies down their cost curves faster than fragmented procurement.

TBI undertook indicative modelling of CDR "bundles", starting with an 80 per cent weighting in nature-based removals in 2025, gradually declining to 20 per cent by 2050. The reverse was applied to engineered removals, the share of which increases as costs fall through scale and learning effects. This pathway would ensure early capital for necessary nature projects while scaling durable permanent removals as they commercialise. Bundle prices

thus could maintain stability: starting around \$83/tCO₂, rising towards \$115/tCO₂ in the early 2030s and then levelling off, reflecting both the increasing share of costlier tech methods and their cost declines.

FIGURE 14

Price of balanced CDR bundles 2025–2050



Source: TBI analysis

Note: The methodology and data for this indicative model are available in the Appendix

But markets alone are unlikely to spontaneously produce credible CDR bundles. Governments thus have a powerful role to play, ensuring that this solution is treated as a financial product with credibility. Governments should:

Set CDR-bundle standards: Defining what qualifies as a CDR-bundle unit, and the ratio pathway for nature-based versus engineered removals

 and aligning these with credible net-zero pathways - would ensure integrity. Variables should also be transparently set to account for differing delivery risk.

2. Create demand: Government-backed CDR bundles should be linked to a demand scheme. Whether through compliance-market integration, a takeback obligation, voluntary markets or even as direct government procurement, creating a sizeable demand for CDR bundles would underwrite their future and guarantee liquidity. Alternatively, governments could license private-sector players to create, manage and sell these bundles, if they follow defined bundle standards.

CDR bundles would not be a panacea, but instead a pragmatic bridge. By balancing immediacy with permanence, and biodiversity with durability, bundles could convert today's fragmented pilot market into a scalable and credible removal system. The task for policy is not to pick which CDR types are the winners of the future, but to underwrite portfolios that let all pathways compete, improve and ultimately deliver the mix of removals required.

NOVEL POLICY APPROACHES: TWO APPROACHES TO TIE AVIATION TO REMOVALS

Aviation is and will continue to be one of the world's most hard-to-abate sectors. Sustainable-aviation-fuel (SAF) mandates in the Europe and UK are ramping up, but the new fuels needed are not developing fast enough to sufficiently reduce airline emissions. The UK's recent Independent GGR review echoes academia in identifying the aviation sector as uniquely placed to benefit from and finance the purchasing of removals, especially engineered, durable removals. For the upcoming few decades, a large share of flights, both in Europe and globally, will continue to run on conventional kerosene. Removals mean there is more that airlines and jetfuel producers can do. The following two recommendations identify policies that could kickstart the aviation sector's role in removals.

RECOMMENDATION	ARCHETYPE	OUTCOME
Jet-fuel sellers and European buyers should integrate CDR into sales of jet fuel and SAF mandates	Fossil-fuel-rich exporters	Tackles insufficient investment and scaling frameworks

Fossil-fuel-rich exporters could turn decarbonisation into a feature of fuel sold by selling jet fuel (known as A-1) integrated with durable carbon removals. The commercial and regulatory infrastructure exists for a new proposition: to sell the fuel and the verified, permanent removal together. Done right, this would not be another round of offsetting and a licence to pollute, but rather a compliance-ready product built to comply cleanly with new EU and UK rules, as well as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) regime.

The European and UK A-1 market offers a strategic opportunity as an import-dependent market with SAF mandates and aviation carbon taxes already in place. Gulf producers are the majority supplier of European jet-fuel consumption, while Norway and Denmark are turning their areas of the North Sea into carbon-storage destinations. At the same time, the EU has legislated for further build-out of CO₂ storage and the UK is integrating engineered permanent removals into its emissions-trading system.

For jet-fuel exporters, this is more than just a reputational uplift. It hedges against tightening climate policy in buyer markets and is a way to further monetise existing domestic investments in DACCS, BECCS and other forms of CCS. For airlines, this would lower their administrative burden and reduce their overall emission footprint. Each unit of jet fuel plus CDR adds to the price of the fuel on a cents-per-litre basis.

FIGURE 15

Figure 15 CDR jet-fuel cost addition per tonne of CO2 removed

CDR jet-fuel proportion	€/L at €100/t	€/L at €200/t	€/L at €400/t	Â
1%	0.0025	0.0050	0.0100	
5%	0.0125	0.0250	0.0500	
10%	0.0250	0.0500	0.1000	Ţ

Source: TBI analysis

Note 1: We assume 2.5kgCO₂/L A-1. Durable CDR prices between €100-400/t

Note 2: Cost = 0.0025tCO₂/L × uplift × €/t

How Would It Work?

The fuel supplier delivers standard kerosene and retires a defined share of durable removals against the fuel's expected emissions, starting with 1 to 10 per cent, and then increasing this up to 100 per cent by 2050. At today's removal prices, low single-digit uplifts add only a few eurocents per litre, which is small enough to pilot without price shocks and big enough to start moving real money into permanent carbon sinks.

Two features make this credible. First, the certificates must be the right ones for the right regimes: EU-certified removals when the uplift is claimed in the EU, UK-approved engineered removals for the UK and CORSIA-eligible units where airlines need offset cancellations for international flights. Second, no double counting or utilisation: once a removal is attached to a fuel batch it is retired with a "no further use" warranty and cannot be reused for the airline's ETS obligations or for CORSIA. Carbon captured cannot be used for increasing fossil-fuel extraction but instead must be permanently stored.

In order to maintain an incentive for investment and innovation in SAF alongside durable removals, policymakers should consider having dual SAF and CDR mandates for aviation, or price-matching CDR purchases with SAF prices. This agnostic approach would reduce the risk of providing perverse incentives that skew investment away from either technology.

For exporters, jet fuel plus CDR would protect market share in a decarbonising Europe and create a new revenue line that capitalises on domestic CCS investments. It would also reframe the relationship with airline customers, changing it from a commodity sale to a compliance solution. For policymakers, such a solution would channel private capital into the carbon-management infrastructure that net zero requires without rewiring existing trading systems. For airlines, this would offer a credible way to take a visible bite out of residual emissions while the SAF ramp-up continues.

RECOMMENDATION	ARCHETYPE	оитсоме
Consider private-jet-removal mandates	High-income industrialised countries and tech and policy pioneers	Tackles standards, policy volatility, insufficient investment and scaling frameworks

A mandate that obliges operators of private jets to pair every flight with certified carbon removals would tackle four market barriers at once. First, it would create reliable demand for high-integrity removals, which are currently too dependent on patchy corporate voluntary purchases. Second, it de-risks early projects by anchoring offtake, helping capital-intensive engineered options scale and learn. Third, it mandates quality, because it can require quality and permanence that match government rules rather the voluntary market rules. And fourth, it stabilises prices by broadening the buyer base, reducing the uncertainty that deters investment. Aviation is a classic hardto-abate sector: while efficiency gains and SAF will help, residual emissions will remain for years and SAF build-out is behind schedule. Requiring aviation to neutralise residual emissions with removals not only respects the science - CDR is necessary, but not a substitute for abatement - but also targets it where substitution is the hardest. A mandate could also be permanence weighted: nature-based tonnes early on, tilting progressively to engineered, permanent removals as supply scales, mirroring the "CDR bundles" set out earlier in this paper. Most of all, it places the financial responsibility of removals at the feet of those most able to pay it.

HOW WOULD IT WORK AND ENSURE INTEGRITY?

• **Scope:** All chartered, non-scheduled private aviation departures above a specific weight/seat threshold

- Obligation: Retire removal credits equal to 100 per cent of flight CO₂ using units certified under government standards
- Trajectory: Start with acceptance of nature-based credits and shift towards permanent removal credits by 2030–2035, or use "bundled" credits with a faster ramp to permanent removals from the beginning
- Administration: Verification based on flight plans; compliance audited through national registries

WHAT WOULD IT COST?

Using this report's bundled CDR-credits pricing: around \$100/tCO₂e.

Using today's high price for only permanent removals: around \$500/tCO₂e.

Prices for permanent removals today are high but are likely to reduce as costs decrease from scaling and learning-by-doing.

FIGURE 16

Cost addition of a private-jet-removal mandate

Route & aircraft (example)	Typical charter (one-way)	Fuel burn used	CO ₂ (t)	Cost add @ \$100/t	Cost add @ \$500/t
London to Paris (light jet, Cessna CJ3)	~\$5,000-\$8,000	~110gph	~1.16t	~\$116	~\$579
London to Marrakesh (midsize, Dassault Falcon 2000)	~\$22,000-\$28,000	~280gph	~6.97t	~\$697	~\$3,483
London to New York (heavy, Gulfstream G550)	~\$67,000-\$71,000	~358gph	~25.7t	~\$2,570	~\$12,848

Source: TBI analysis; charter-price benchmarks from Compare My Jet and Pere Jets; fuel-burn rates from AOPA, AviaCost and Liberty Jet; conversion factors from the Department for Energy Security and Net Zero

Compounding this, private jets are a symbol for perceptions of climate unfairness. A private-jet-removal mandate would apply the "polluter pays" principle where ability to pay is highest, while channelling funds into verifiable carbon sinks. That allows governments to demonstrate tangible action for citizens on emissions and inequality: luxury emissions are paired with durable removals (restored ecosystems now; geological storage tomorrow), in a way that doesn't hurt or hamper the average citizen.

A private-jet removal mandate would smooth the path for a removals industry that the world will soon need, without pretending that offsets absolve aviation of the hard graft of cutting emissions. The policy could be fiscally light, technologically pragmatic and politically populist. In the age of the climate paradox, this is a rare combination.

Pillar 3: Plan Strategically and Integrate Nationally

Carbon removals must be embedded within coherent national strategies that link climate ambition to industrial policy, land management and economic planning. Governments should develop national CDR strategies that set clear targets and governance frameworks, supported by ecosystem-restoration goals that translate land pledges into measurable tonnes of CO₂ removed. Integrated siting maps and planning portals could align land, energy and storage infrastructure to accelerate project deployment, while collaborative CO₂-storage networks can turn geological capacity into a shared, exportable service industry. Together, these measures could transform removals from scattered projects into a long-term, coordinated national agenda.

RECOMMENDATION	ARCHETYPE	OUTCOME
Develop a national CDR strategy	All countries	Tackles scarce resource management and insufficient scaling frameworks

Each country needs a coherent national strategy to integrate carbon removals into its wider climate and industrial planning. A credible CDR strategy should set clear targets, define governance and measurement frameworks, and align energy, land, agriculture, storage and labour systems

to enable rapid deployment and long-term durability. It should clarify the role of removals within mitigation hierarchies, ensuring they complement, not substitute, deep emissions cuts. Such a strategy anchors investor confidence, directs finance and policy, and builds a shared and clear narrative around new economic opportunity as well as climate necessity.

FIGURE 17

The opportunities of a national CDR strategy

For	A national CDR strategy can
High-income industrialised countries	Align R&D investment and market infrastructure, accelerate deployment of engineered solutions, and create exportable expertise and products.
Land-rich LMICs	Connect restoration targets to natural development, food security and access to global carbon finance.
Fossil-fuel-rich exporters	Offer a roadmap to build out storage hubs, develop new CDR-integrated products, and build out CCS supply chains for BECCS and DACCS.
Tech and policy pioneers	Provide a platform for digital MRV innovation, bundled credit design, AMCs and new market instruments that can shape global standards.
Vulnerable low-emitting countries	Link ecosystem restoration and blue-carbon projects with resilience and community livelihoods, cementing land rights through tech, and turn adaptation into exportable value.

Source: TBI

Governments could also upgrade existing restoration targets into measurable, investment-grade components of national CDR strategies. This means translating hectares restored into tonnes of CO₂ removed, embedding them in national accounting systems and aligning them with domestic finance, permitting and MRV frameworks. Restoration targets should also be used to guide land-use planning: identifying priority zones where ecological recovery, carbon storage and local development goals overlap.

Some countries are beginning to show what this looks like in practice. The UK's Nature for Climate Fund links afforestation and peatland restoration directly to national carbon budgets, while Kenya's National Tree-Growing and Restoration Strategy ties its forest-restoration target to carbon-market

access and local job creation.^{61,62} Replicating this approach globally would help restoration act not only as an environmental goal but as a credible, financeable pillar of national CDR delivery.

A national CDR strategy is not just a climate-action plan, but rather should be an industrial, land-use and fiscal blueprint for a carbon-managed economy and new economic sector. One that positions nations to seize the economic and environmental dividends of the transition.

RECOMMENDATION	ARCHETYPE	ОИТСОМЕ
Provide siting maps that couple resource needs (renewables, storage, water) into planning portals, cutting site-selection times.	All, especially land-rich LMICs	Tackles scarce resource management, and transport and supply-chain coordination

A major obstacle for scaling carbon-removal projects, especially for engineered removals, is the lack of coherent, easily accessible spatial data to identify viable sites. Developers often face a patchwork of information: forest inventories from one agency, renewable-energy zones from another, and geological or soil maps from a third, with little integration between them. This fragmentation can add months or years to permitting timelines, inflate project costs and deter private investment altogether.

Governments should therefore develop integrated national siting maps that overlay critical resource layers, such as renewable-energy potential, water availability, land type and use, soil quality, biomass supply chains, and access to CO₂ transport-and-storage infrastructure. These maps should be made accessible through government-backed planning portals, ideally linked to existing geospatial systems or "one-stop" licensing tools. The objective is to reduce site-selection times, de-risk investment and ensure that CDR deployment complements, rather than competes with, other national land and energy priorities.

In practice, these maps could resemble the Hydrogen Project Directory, which visualises potential production and storage sites based on existing pipelines, industrial clusters and renewable zones, or Kenya's National Spatial Plan, which integrates land-use, infrastructure and conservation data for investment planning. 63, 64 Countries like Denmark and Norway are also

mapping geological-storage capacity alongside renewable resources to accelerate carbon capture, utilisation and storage (CCUS) deployment; a similar model could be adapted for CDR siting in land-rich LMICs, incorporating soil carbon and afforestation potential alongside layers identifying renewable energy potential and water availability.

By embedding such tools within broader national CDR strategies, governments can direct investment toward "priority" zones: areas where resource synergies are high and conflict risks are low. This also allows planners to pre-screen for environmental and social safeguards, align with restoration or agricultural targets, and accelerate approvals for compliant projects. Over time, these systems can evolve into dynamic planning platforms, incorporating remote-sensing data and Al-driven updates to reflect changing land conditions and project performance.

In short, integrated siting maps are not just a bureaucratic upgrade. They are an essential piece of enabling infrastructure. By reducing uncertainty and aligning ministries, governments can move from ad-hoc project siting to a coherent national pipeline, making CDR investment faster, cheaper and more credible.

Sirona Technologies

Belgian CDR start-up Sirona Technologies is deploying modular, containerised DACCS in Kenya's Great Rift Valley and pairing it with permanent mineral storage. In February 2025 Sirona launched Project Jacaranda at Lake Elementaita with storage partner Cella, integrating solar power, DACCS and in-situ carbon mineralisation in local basalts. Sirona states that its pilot became operational in January 2025 and was the "fastest" DACCS pilot deployment to date, followed by the unveiling of its first commercial DACC container in July 2025 with plans to deliver its first certified DACCS credits by December 2025. Early market traction includes an offtake with engineering consultancy Hexa.

The Kenyan location is strategic for scaling DACCS: the country's grid was approximately 90 per cent renewable in 2023 (with geothermal energy accounting for 47 per cent of this), providing low-carbon energy to run DACCS, while the Great Rift Valley's extensive basalt formations enable Cella's process of dissolving CO₂ in water and injecting it underground where it mineralises into stable carbonates. Great Carbon Valley is working with Sirona to develop a regional DACCS hub that leverages this mix of geology and power. Sirona's factory-built, low-capex, plug-and-play units and early buyers together de-risk deployment and signal a replicable pathway for durable DACCS in East Africa.

RECOMMENDATION	ARCHETYPE	OUTCOME
Collaboratively build out CO ₂ storage networks	All, especially fossil-fuel-rich exporters	Tackles enabling infrastructure and insufficient investment

To scale removals fast, countries that export hydrocarbons could not just capture carbon at home but also sell storage as an open-access service to emitters. Care is needed to ensure such a service doesn't deter the phase-out of fossil fuels. However, Norway has shown how to bring together industry, capital and infrastructure into a cross-border network while also reducing overall oil production volumes. The same template, tweaked for local geology, governance and politics, fits contexts around the world.

Norway absorbed "first of a kind" risk by providing around €1.9 billion in grants to Northern Lights JV, a consortium of oil and gas giants Equinor, Shell and TotalEnergies, towards an approximately €2.9 billion carbon-capture and storage programme, covering construction and ten years of operation. These investments and grants meant the private sector had the confidence to invest, including cement producer Heidelberg, waste-to-energy operator Hafslund Oslo Celsio and BECCS operator Stockholm Exergi. 66

The government funded Phase 1, the open-access transport-and-storage facility, up front, absorbing early volume risk. Together with a 15-year offtake from Stockholm Exergi, the Northern Lights JV then took on Phase 2, expanding capacity to ≥5Mt/yr.

Collaborative models like this can and should be replicated elsewhere. The Gulf's major oil companies – ADNOC, Aramco and QatarEnergy – each have DACCS and CCUS projects of their own, with storage targeted in local saline formations and sinks. The region also has vast storage potential, with theoretically enough storage for more than 25 times all human-made emissions in Oman alone. In South America, Brazil's Petrobas has reached carbon-injection milestones. These state-backed oil majors should collaborate regionally on storage solutions to share research and infrastructure costs, each then sharing in the future opportunities. Trinidad and Tobago and Guyana have set up legal frameworks for carbon storage, preparing for a future market. They too should collaborate with their neighbours where possible to develop open-access storage schemes.

Permanent CO₂ storage is the next export for fossil-fuel economies: take first-of-a-kind risk on an open-access transport-and-storage utility, set clear cross-border rules and bankable MRV and let private capital scale. Do that and geology becomes a service industry, selling durable removals to the world while lowering domestic transition costs.

Pillar 4: Empower Small Players and Communities

Scaling carbon removals equitably requires empowering the people and places that steward land, forests and coastlines. Implementing these measures will build the social, legal and institutional foundations for an inclusive carbon-removal economy: one that delivers market credibility and enhanced livelihoods alongside climate results.

RECOMMENDATION	ARCHETYPE	OUTCOME
Launch aggregation platforms for small projects	All, especially vulnerable low-emitting countries	Tackles insufficient scaling frameworks

An aggregation platform is a legal and operational entity, like a co-op, that pools micro-scale (and often smallholder-led) CDR projects into a single portfolio for finance, contracting, MRV, risk management and credit issuance.

In practice, an aggregation platform serves various roles, including:

- · Registering with national or international carbon registries
- Issuing standard contracts to project participants (communities, farmers, landowners) with clear roles and revenue-sharing
- Collecting baseline and monitoring data
- · Performing sampling and scaling of results
- · Liaising with buyers or financiers

The platform can be divided into tiered sub-portfolios by CDR method (e.g. blue carbon, peat, soil, biochar) to reduce heterogeneity and tailor MRV protocols, or it may issue tranche-based risk buffering (e.g. first-loss reserve).

A particularly promising model within this approach is the cooperative biochar platform, in which groups of farmers, indigenous groups or rural enterprises co-own and operate small modular pyrolysis units to produce biochar and verified carbon removals. For example, PlantVillage+, a community cooperative operating across Africa, has developed its own pyrolysis system that can be constructed in days and be easily deployed to where crops are harvested, so that waste biomass can be pyrolysed on site, enabling farmers and local stakeholders to generate revenue from credit sales.⁷¹

In addition to this, the cooperative empowers farmers by allowing them to sell the biochar they have produced and receive income from verified biochar carbon credits. The cooperative's end-to-end approach ensures quality, traceability and scalability, in turn letting organisations and individuals integrate their carbon credits into sustainability reporting. Rather than simply supplying feedstock to external developers, these cooperatives retain ownership of the biochar and the resulting carbon credits, keeping the credit revenue within the community. Through aggregation, multiple cooperatives can link under a shared legal and MRV framework, for example through a regional cooperative trust or carbon-aggregation entity, which handles registry registration, credit issuance and buyer engagement on behalf of members. In addition, aggregation also opens up new sources of capital by reaching thresholds that make investment more attractive to large players.

Community-scale aggregation is already delivering saleable removal credits in coastal and forest systems. For example, the Mikoko Pamoja⁷² and Vanga Blue Forest⁷³ projects in Kenya aggregate community mangrove restoration and conservation under the Plan Vivo Biodiversity Standard. Together they involve more than 2,000 households, generating more than 41,000 credits while funding local education, health, sanitation and water initiatives.

To promote aggregation platforms further, governments should consider establishing national or regional aggregation gateways that pre-approve eligible practices (such as mangrove and peat re-wetting, smallholder agroforestry, enhanced rock weathering or cooperative biochar production), bundle project documentation and standardise community-benefit terms.

This lowers entry barriers for smallholder farmers, fishers and foresters while ensuring consistent governance, technical quality and social safeguards across micro-projects.

RECOMMENDATION	ARCHETYPE	OUTCOME
Provide technical assistance for landowners and communities to enable them to implement carbon-removal practices	All, especially land-rich LMICs and vulnerable low- emitting countries	Tackles insufficient scaling frameworks

Technical-assistance programmes for carbon-removal projects must go far beyond cursory training. They need to embed deep, practical expertise across every stage of the project cycle, including:

- Site-suitability screening (soil carbon potential, hydrology, climate, baseline fluxes)
- Species and site matching (for afforestation, mangroves, peat and wetland restoration)
- Carbon-safe agronomic practices (reduced tillage, biochar integration, cover cropping, composting)
- · Adaptive management protocols (monitoring, repair, replanting)
- · Ecological co-benefit design (biodiversity, water, livelihoods)
- Local monitoring and verification capacity development

In practice, governments or donors should equip landowners and local institutions with technical CDR toolkits that include handheld remotesensing devices, geographic-information-system (GIS) and MRV software, and standardised field protocols. These kits enable consistent data collection and promote regional knowledge networks for sharing best practices and innovations. Embedding training on monitoring and verification also allows local actors to perform parts of MRV themselves, reducing long-term dependence on external consultants and improving data integrity. Training for biochar and enhanced rock weathering, in particular as land-based durable CDR methods, should be integrated into national agricultural-extension services.

Open, no-cost digital tools already provide a foundation. The FAO's Open Foris platform offers cloud-based workflows for afforestation and soil-carbon monitoring, while the NDC Partnership supports countries in designing MRV systems and building institutional capacity. Governments can promote these models through extension-type education, linking forestry, agriculture and environmental agencies with universities and technical colleges to deliver short courses in restoration science, carbon accounting and project design.

Vi Agroforestry

The Kenya Agricultural Carbon Project (KACP)⁷⁶ led by Vi Agroforestry is a soil carbon-sequestration programme working with smallholders around Kisumu and Bungoma to adopt sustainable agricultural land-management (SALM) practices⁷⁷ that incorporate agroforestry, cover crops, mulching, composting, terracing, reduced tillage and water harvesting. These initiatives are monitored and credited under standard-setter Verra's Verified Carbon Standard (VCS) methodology VM0017,⁷⁸ which was originally developed with the World Bank BioCarbon Fund.

In January 2014, it issued the world's first VCS soil carbon credits for SALM (24,788 tCO₂e) and reported increased yields of 15 to 20 per cent alongside carbon revenue streams. Subsequently, the World Bank agreed to purchase a portion of credits (\$600,000 by 2017). Designed as a livelihood-plus-climate intervention, KACP couples on-farm advisory with farmer groups, village savings and loan associations to scale practice uptake and MRV, and has been documented academically as improving SALM adoption and resilience in the Lake Victoria basin.

RECOMMENDATION	ARCHETYPE	оитсоме
Establish regional restoration and CDR hubs	All, especially land-rich LMICs and vulnerable low- emitting countries	Tackles policy and pricing volatility, and high costs

Delivering high-quality, durable carbon removals requires not only finance and policy frameworks but also local infrastructure and institutional capacity. Governments should therefore establish regional restoration and CDR hubs:

semi-centralised facility networks that combine physical infrastructure with technical services to support the scaling of both nature-based and engineered removals.

Each hub could serve as a regional anchor, housing nurseries, seed banks, propagation labs, tool libraries and greenhouse capacity alongside training centres, field mobilisation teams and data systems. Staff can maintain biodiversity-proven seed collections, conduct species and soil trials under different microclimates, and maintain control plots to refine carbon-uptake curves. Hubs should also manage a digital registry of local projects, tracking survival rates, success metrics and best practices to create a feedback loop that improves project quality and permanence.

Policy can enable these hubs through capital grants or concessional funding for start-up costs, nurseries, laboratories and monitoring platforms. Governments could also mandate hub participation in sub-national CDR funding disbursements and require community contracting through performance-based payments. For land-rich LMICs and vulnerable low-emitting countries, this approach can be transformative: it turns natural capital into a structured pipeline of investable restoration and CDR opportunities while building long-term institutional capacity. These measures reduce duplication, improve economies of scale and deliver consistent quality control – functions that individual small projects often cannot achieve.

Examples already exist. The IORA Indian Ocean Blue Carbon Hub, hosted by the Commonwealth Scientific and Industrial Research Organisation, convenes countries across the Indian Ocean to strengthen blue-carbon science and policy; the UNEP Nairobi Convention has developed regional MRV workshops to align coastal restoration with international commitments. ⁷⁹ Financial innovation can reinforce this model: blue bonds and debt-fornature swaps, as seen in Belize and the Bahamas, can endow hubs with durable capital for feasibility studies, biomass sampling and early-stage community outreach.

Regional restoration and CDR hubs create a physical and institutional backbone for large-scale removals. By aggregating infrastructure, knowledge and finance, they turn scattered projects into coherent regional industries: helping every country, from high-income industrialised economies to vulnerable low-emitting countries, move from pilot projects to pipelines of verified carbon removal.

RECOMMENDATION	ARCHETYPE	ОИТСОМЕ
Legislate for land-rights digitalisation and community profit-sharing	All, especially land-rich LMICs	Tackles scarce resource management and policy volatility

The foundation of credible carbon removal lies in clear, enforceable land ownership and clear rules about the rights to the carbon stored on that land. Without these, it becomes difficult to determine who can legally use, manage and benefit from the land and its added carbon value. If a project lacks well-defined land tenure, project legitimacy is put at risk, investment confidence drops, and monitoring and permanence are both more difficult to guarantee. Governments should legislate for participatory land mapping using participatory GIS and community-verified data, and the creation of digitalised registries underpinned by GIS and, where appropriate, distributed-ledger technologies. A neutral state agency should validate and reconcile customary and statutory claims, audit disputes, and issue legally recognised digital land certificates. Once land rights are formalised, CDR project contracts can be securely linked to land parcels, reducing expropriation risk, enabling fair contracting and building investor confidence.

Alongside secure tenure, legislation should enshrine community profit-sharing mechanisms. CDR project contracts should allocate a defined minimum share of carbon revenues to local communities, with transparent oversight through escrow accounts, independent audits and mandatory public disclosure. Revenue disbursement should be tied to verified performance, not just ownership, ensuring communities are rewarded for maintaining carbon storage over time. Strong grievance-redress mechanisms and transparency standards should be built into law to safeguard against corruption and elite capture.

This dual framework – secure, digitised land rights and legally protected community profit-sharing – aligns incentives across the CDR value chain. Farmers, fishers and other local land stewards are far more likely to maintain restoration projects, prevent deforestation and manage peat or mangrove systems when they hold recognised rights and direct financial stakes in their success.

Many countries are already showing the way. Senegal's PROCASEF programme is digitising its land cadastre (registry) to create a single source of truth for tenure and community-benefit distribution, while Mozambique's SiGIT platform provides a transparent, low-cost land-administration system for land rights. For land-rich LMICs and vulnerable low-emitting countries, pairing such digital land registries with formalised benefit-sharing standards could transform local participation in CDR while providing the legal and financial assurances global investors increasingly demand.

Conclusion

Acting to reduce emissions remains non-negotiable, but the need for removals is now unavoidable. The science is settled, and the politics and the economics are now clear on "how": we need to both deploy nature-based solutions now and continue action in the near term to build out engineered durability for the future. Nature-based carbon-removal solutions are fast and affordable, but are reversible and lock up land which may be better used for other purposes. Engineered removal innovations are slower and costlier but durable for centuries or longer, delivering the permanence needed for long-term climate stabilisation. A credible pathway blends both.

There are opportunities to be grasped for all types of countries. To capitalise on them, high-income industrial economies should set standards and buy at scale; land-rich LMICs can turn restoration into livelihoods; fossil-fuel exporters can repurpose subsurface advantage into permanent storage hubs; policy pioneers can trial bundles and insurance; and vulnerable low-emitters can aggregate high-integrity, community-led projects that build resilience.

The best tonne of emissions abated is generally the one that isn't emitted at all. But the next best is the permanently removed tonne we can measure and retire. If we build that capacity now, we can buy time, resilience and a strategic industry for the 2030s and beyond.

Annex

Download the annex as a PDF.

Endnotes

- 1 https://www.ipcc.ch/sr15/chapter/spm/
- 2 https://www.ipcc.ch/sr15/chapter/spm/
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- 7 CDR is distinct from carbon capture and storage (CCS) technology, as the latter focuses on capturing emissions at source, to prevent them from entering the atmosphere in the first place. CCS is therefore not considered a CDR technology and is beyond the remit of this paper.
- 8 Some classifications also use the term "hybrid solutions" to refer to processes that combine technological and natural processes, such as biochar and enhanced rock weathering.
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