

# Climate Finance

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## INVESTING IN ENGINEERED CARBON DIOXIDE REMOVAL IN DEVELOPING COUNTRIES – OPPORTUNITIES AND CHALLENGES

This knowledge note explains what engineered carbon dioxide removal (eCDR) is and why its development and deployment have increased substantially in this decade. It provides an overview of the range of available eCDR technologies at different maturity stages, discusses opportunities and challenges for developing countries to host eCDR projects, and elaborates on emerging financing models for eCDR. The note is of interest to practitioners in development organizations supporting clean technology deployment, policy makers in developing countries, and providers of international climate finance from both the public and private sectors.

### Rationale

eCDR comprises a broad range of technological solutions that remove carbon dioxide (CO<sub>2</sub>) from the atmosphere. This differs from nature-based removal solutions such as afforestation (see the following section for an overview of different eCDR technologies). It also differs from point-source carbon capture, although both are often grouped together under the broader term of carbon management.

Point-source carbon capture, for example, capturing and storing CO<sub>2</sub> from a cement plant, avoids emissions from economic activities that would otherwise happen. It is one of many decarbonization technologies, such as renewable energy and efficiency measures, that can substantially reduce emissions from economic activities and, in some cases, enable near-zero operational emissions (with remaining life cycle emissions depending on technology and

supply chains). Nature-based removals and eCDR remove carbon from the atmosphere and can therefore deliver net-negative outcomes when removals exceed associated life-cycle emissions, that is, they can reduce atmospheric CO<sub>2</sub> concentrations by extracting CO<sub>2</sub> from the air and storing it through 'negative emissions' (=atmospheric removals).<sup>1</sup> Compared with many land-based removals stored in biomass, several engineered removals can offer higher durability (centuries to millennia) depending on the storage reservoir, for example, geological storage, mineralization.

While decarbonization and deployment of nature-based removal solutions are essential to achieve international climate mitigation goals, they alone might not suffice. Global emissions are already overshooting trajectories that would limit global warming to below 2°C. Afforestation and other nature-based removal solutions have natural limits in land availability.

<sup>1</sup> Capture and storage of waste gas from combusting renewable biomass or biogenic waste is a mixed type in being a net-negative point-source carbon capture technology.

Modeled pathways that limit warming to 2°C or lower typically include some level of carbon dioxide removal (CDR), both nature based and engineered. In many scenarios, eCDR scales to gigatons per year by mid-century, alongside deep emissions reductions.<sup>2</sup> These scenarios become more likely the more the world falls behind its mitigation targets.

Despite the present high costs of eCDR—with International Energy Agency (IEA) estimates for direct air capture and storage at roughly US\$500–1,900 per tCO<sub>2</sub> today and first-of-a-kind bioenergy carbon capture and storage around US\$75–300 per tCO<sub>2</sub>, depending on design and context<sup>3</sup>—cost reductions are expected as deployment and learning progress. Costs may eventually approach mitigation costs in some hard-to-abate sectors.

One of the main advantages of non-bioenergy eCDR is geographic flexibility since it does not need to be collocated with the source of emissions and can therefore leverage sites that have access to abundant renewable energy, cheap land, promising geology for storage, potential for soil improvements through mineralization, and distance from population centers.

## Status of eCDR deployment

CDR today is around 2 GtCO<sub>2</sub> per year, almost all from conventional land-based methods; novel CDR contributes about 1.3 million tons per year (less than 0.1 percent of total) but is growing faster than conventional approaches.<sup>4</sup> In mitigation scenarios that

rely on eCDR, rapid eCDR development and deployment will be needed.

Against this background, some governments are increasingly promoting eCDR, as evidenced by programs in the US, the European Union (EU), and the UK, among others.<sup>5</sup> Results-based payments for CDRs have emerged as a key instrument to promote eCDR technologies that often do not produce any other good than climate mitigation.

According to CDR.fyi, which tracks the durable CDR market, purchasers have spent about US\$11 billion to contract roughly 44 million tons of removals to date. However, only 2.8 percent of contracted volume has been delivered so far, highlighting the project development and delivery lag in early markets.<sup>6</sup>

eCDR credits score high on environmental integrity and additionality. Carbon crediting standards are expanding their coverage of climate mitigation activities to eCDR, with currently 30 methodologies for different types of eCDR projects available from independent carbon standards and governmental bodies.<sup>7</sup>

eCDR credits are widely seen as a growing carbon market business area, albeit starting from a small basis for delivered credits. Standards are evolving rapidly and the Science-Based Target Initiative (SBTi) in its current net-zero standard limits neutralizing residual emissions in net-zero claims to removals with durable storage.<sup>8</sup>

2 The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (2022), <https://www.ipcc.ch/report/ar6/wg3/>.

3 International Energy Agency. 2025. "Driving Down the Cost of Carbon Removal: Why Innovation Matters." <https://www.iea.org/commentaries/driving-down-the-cost-of-carbon-removal-why-innovation-matters>.

4 The State of Carbon Dioxide Removal, 2nd edition (2024), <https://www.stateofcdr.org/>.

5 For an overview of governmental efforts to promote eCDR, see Zimmermann, N. 2024. Managing Atmospheric Carbon Levels - A Survey of Carbon Dioxide Removal (CDR) and Carbon Capture, Utilization, and Storage (CCUS) Technologies, Their Prospective Role in Climate Policy, and Emerging Support Mechanisms. <https://www.tcafwb.org/sites/default/files/2024-10/Carbon%20Removal%20final%20report.August%202024.pdf>.

6 <https://www.cdr.fyi/>, accessed February 2026

7 Carbon Counts. 2025. Carbon Crediting Standards for Technology-Based Carbon Dioxide Removal in Developing Countries. [https://fe2f5fab-af08-4152-bf6f-20b2248d2007.usrfiles.com/uqg/fe2f5f\\_b4b9897b8e204c3584f54e49e4d90216.pdf](https://fe2f5fab-af08-4152-bf6f-20b2248d2007.usrfiles.com/uqg/fe2f5f_b4b9897b8e204c3584f54e49e4d90216.pdf).

8 SBTi Corporate net-zero standard version 2.0 - Draft for Second Public Consultation November 2025, <https://files.sciencebasedtargets.org/production/files/CNZS-V2-Second-Consultation-Draft.pdf?dm=1762285041>.

However, note that SBTi standards can change over time and current exclusive focus on eCDR might shift.

The Oxford Offsetting Principles suggest a complete transition of carbon crediting to eCDR over time.<sup>9</sup>

eCDR development and initial deployment are currently mainly in developed countries (89 of a total of 114 projects as of end-2025).<sup>10</sup> Governments in developing countries and eCDR investors are looking less at prospects for eCDR in developing countries.

### eCDR technologies and deployment readiness

An overview of both eCDR technologies and nature-based removal solutions is provided by the The Intergovernmental Panel on Climate Change (IPCC).<sup>11</sup>

Whereas nature-based CDR binds carbon in relatively short-lived vegetation through afforestation and land restoration, eCDR technologies store CO<sub>2</sub> in geological reservoirs or bind carbon in minerals or durable products, keeping it out of the atmosphere for centuries to millennia. As can be seen in Figure 1, many removal solutions share natural and engineered elements but are clearly distinguished by length of storage.<sup>13</sup>

Bioenergy with carbon capture and storage (BECCS) is the best-known eCDR technology. BECCS plants combust waste or renewable biomass to generate energy (electricity or heat), capture CO<sub>2</sub> from combustion, and store it in geological reservoirs.

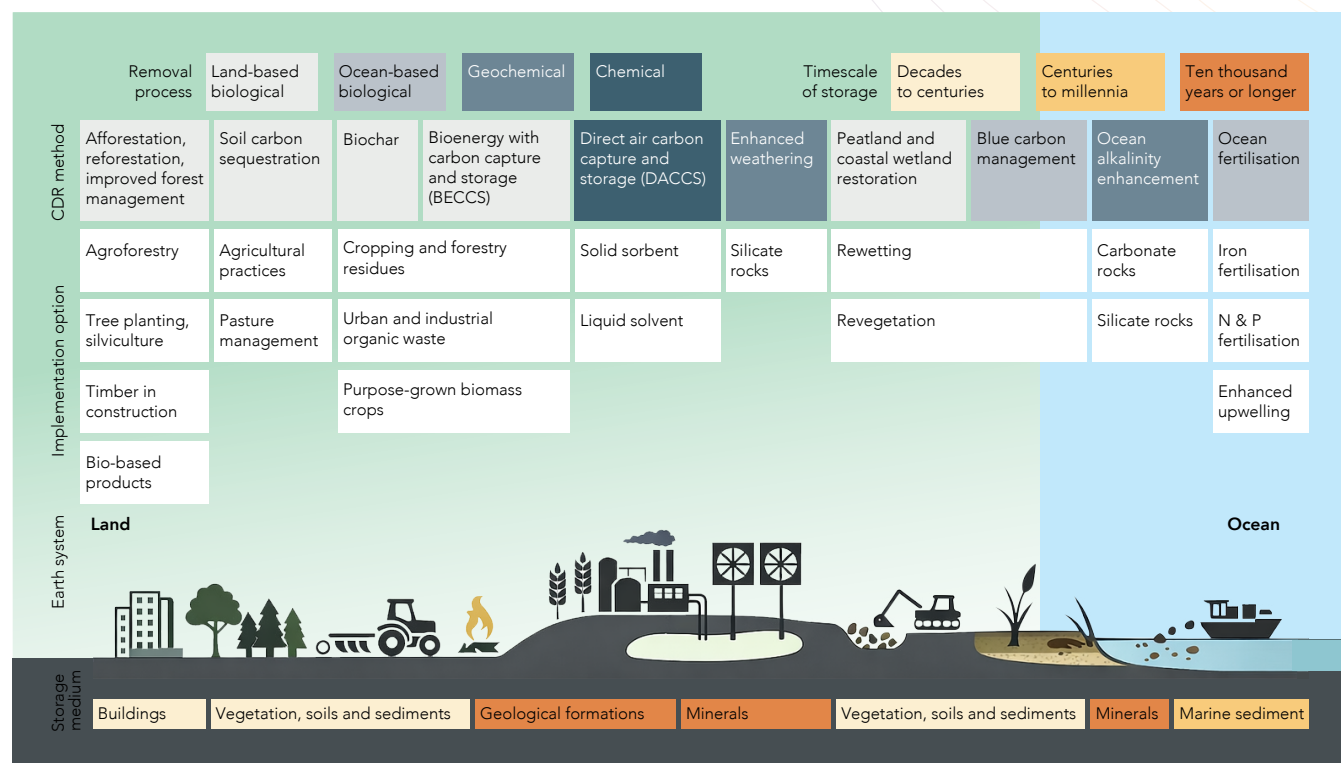


Figure 1: Engineered and nature-based removal solutions  
Source: IPCC.<sup>12</sup>

9 Oxford Principles for Net Zero Aligned Carbon Offsetting (revised 2024), <https://www.smithschool.ox.ac.uk/research/oxford-offsetting-principles>.  
 10 Carbon Counts (2025). From the 25 eCDR projects in developing countries, 4 fall in the category of enhanced rock weathering (ERW) and the remaining are all biochar projects with soil storage which are at the border line of nature-based solutions.  
 11 IPCC (2022).  
 12 IPCC (2022).  
 13 The following descriptions of key eCDR technologies benefited from the use of an AI tool reviewed for correctness and was informed by Carbon Counts (2025).

This is a mature technology and methodologies to quantify and monitor, verify, and report removals are available with limited complexity in application.

Direct air carbon capture and storage (DACCS) pulls ambient air through equipment where CO<sub>2</sub> chemically binds to solid sorbents or liquid solvents. The capture material is then heated to release concentrated CO<sub>2</sub>, which is compressed for handling while the sorbent/solvent is regenerated and reused. The CO<sub>2</sub> is then injected into suitable geologic formations for permanent storage. This is a tested technology with limited monitoring, reporting, and verification (MRV) complexity. It is energy intensive and only suitable where there is abundance in renewable power generation.

Enhanced rock weathering (ERW) spreads finely crushed silicate rocks (for example, basalt) on soils to accelerate natural weathering reactions. Rainwater and soil CO<sub>2</sub> form carbonic acid that reacts with minerals, consuming atmospheric CO<sub>2</sub> and converting it into dissolved bicarbonate ions. The bicarbonate ions are carried via groundwater and rivers to the oceans, where the carbon is stored for thousands to millions of years in dissolved form and ultimately in sediments, delivering durable CO<sub>2</sub> removal and helping counter ocean acidification. While this technology is basic, the required MRV is highly complex and still being refined. Two registries, Puro and Isometric, have registered several projects and issued credits, but most have remained at the pilot stage.

Under the London Convention and London Protocol, parties agreed that—given current knowledge—ocean fertilization activities other than legitimate scientific research should not be allowed. Research proposals are assessed case by case under an agreed assessment<sup>14</sup> (London Convention) and direct ocean

alkalinity enhancement is being evaluated under the London Convention. Both eCDR technologies face high MRV complexity and are limited to research activities with potential deployment at a later stage.

Biochar-based CDR converts biomass via pyrolysis into a more stable carbon-rich solid that, when applied to soils, can store carbon for centuries to millennia, depending on feedstock and conditions. Use in durable materials (for example, construction products) can also provide durable storage pathways. MRV requirements are pathway specific and typically focus on feedstock sustainability, process emissions, and quantifying of stable carbon fractions. In all cases, MRV is complex.

## Opportunities and challenges of deploying eCDR in developing countries

Opportunities for developing countries in eCDR could be substantial. eCDR in developing countries could be driven primarily through foreign direct investments from developed countries generating revenue. Developing countries might have comparative advantages in deploying eCDR in terms of resource availability, that is, labor, land, and energy. Underlying geology is a major determinant of permanent geological storage, and some developing countries have already been identified for promising fundamentals, such as basalt in Kenya and depleted oil and gas fields in Nigeria. Carbon storage as a service could generate royalties for the host countries. However, even for more mature eCDR technologies such as DACCS, BECCS, and ERW, a global mapping of potential and related costs is not yet available, leaving prospects for developing countries hypothetical for the time being.<sup>15</sup>

14 For details on the London Convention, see the International Maritime Organization, <https://www.imo.org/en/ourwork/environment/pages/london-convention-protocol.aspx>.

15 For ERW, climatic suitability matters: one techno-economic assessment finds the largest cropland potentials concentrated in warm, humid regions—particularly parts of India, Brazil, Southeast Asia and China (Strefler, J., et al. 2018. "Potential and Costs of Carbon Dioxide Removal by Enhanced Weathering of Rocks." *Environmental Research Letters* 13 034010. <https://iopscience.iop.org/article/10.1088/1748-9326/aaa9c4>.)

Besides revenue generation, some eCDR technologies can have positive development co-benefits such as improving agricultural productivity in applying alkaline rock powder to agricultural soils for ERW or energy generation for BECCS.

Deploying eCDR is an entirely new economic activity in most countries and will require capacity building, technology transfer, and political and societal buy-in. In a recent assessment of eCDR inclusion in climate policy planning in developing countries, including Nationally Determined Contributions (NDCs) and Long-term (decarbonization) Strategies (LTSs), only seven countries consider eCDR as an option in their climate mitigation efforts (Bahrain, Brazil, Indonesia, Oman, Saudi Arabia, Thailand, and the United Arab Emirates).<sup>16</sup>

Cost and technical maturity are the major challenges for most eCDR technologies. While technologies can be rather basic in some cases, such as in ERW or biochar use, there are still very few applications, and experiences with (commercial-scale) project performance are limited. For energy-intensive eCDR, such as direct air capture, there are potential concerns over allocation of energy use for development priorities (although this can be mitigated by treating the CDR asset as an anchor consumer for new generation).

Depending on the method of carbon storage used for eCDR projects, many of the challenges facing 'traditional' carbon capture and storage will also apply. These include community engagement for siting the pipelines and storage, needing permitting clarity for the pipelines and storage, monitoring for leakages, and allocation of financial and physical liability.

Quantification of removals is complex and demanding for eCDR technologies other than BECCS and

DACCS. Even where eCDR projects do not participate in carbon market transactions, removals need to be quantified to allow projects to deliver tangible outputs. Quantification should (and in case of carbon market transactions must) be done on an ex post basis through appropriate MRV. Such quantification methodologies and MRV procedures are in the early stages of development, with some methodologies already available under various carbon standards, but most still lack a track record of successful application.

Reversal risks are generally lower for eCDR compared to nature-based solutions, but they still need to be addressed with solutions that can build on approaches used in the nature-based space, such as buffers and/or insurance solutions.

Finally, the incompleteness of national greenhouse gas inventories is an accounting challenge. While project emissions from eCDR are typically reflected in inventories, for example, energy-related emissions from pulverizing rock in the case of enhanced weathering, removals most often will not. In hosting an eCDR project, a country might therefore see an increase in domestic emissions if the removals are not captured in its inventory. Similarly, a reversal, such as leakage of stored CO<sub>2</sub> from a reservoir, can lead to an increase in inventory emissions. Countries with climate mitigation targets could therefore experience negative effects on target achievement from hosting an eCDR project, even if no carbon market transaction is undertaken. A carbon market transaction would exacerbate the situation further if transferred carbon credits were added to the country's emission balance, as for transactions under Article 6 of the Paris Agreement.<sup>17</sup>

This accounting challenge can be addressed by improving inventories where needed. In most cases, it would not disqualify piloting activities with marginal impact on

16 Carbon Counts (2025). These countries referred either to BECCS or DACCS. More countries referred to carbon capture and storage, that is, removal of carbon and storage from waste gases from energy production and industrial processes with sometimes unclear distinction to eCDR.

17 Inventory incompleteness can become an issue for all types of carbon crediting transactions and not only eCDR.

national emissions, but it needs to be addressed once eCDR is to be deployed on a larger scale.<sup>18</sup>

Considering the opportunities and challenges for developing countries in engaging in eCDR, it seems fair to recommend a cautious and no-regret strategy taking advantage of possibly attracting foreign direct investments. This could start with assessing opportunities and capacity needs, potentially leading to a first generation of pilot projects. Advanced countries could support this process through public-private partnership programs facilitating investments in eCDR through the right financial instruments complemented by strong knowledge and capacity-building programs.

## Financial instruments and strategies to pilot eCDR in developing countries

Given the nascent stage of eCDR technologies and deployment, finance for such projects is scarce even in developed countries. Projects in emerging markets are significantly limited. Globally, only slightly more than US\$10 billion (roughly 23 percent of total CDR capital raised) has been specifically committed to engineered solutions like DACCS and BECCS as of late 2024.<sup>19</sup> The early 2020s were a time of rapid capital fundraising for eCDR. The momentum for venture capital and private equity investments for eCDR, and DACCS in particular, however, waned in 2025. The United States remains the leading market for DACCS projects. However, in the absence of renewed policy support in the short term, it is likely that there will be further acquisitions and absorption of eCDR technologies by larger interests, such as Occidental Petroleum's acquisition of Carbon Engineering and Holocene, two DACCS companies.<sup>20</sup>

Demand remains highly concentrated. The IEA notes that about 65 percent of purchases of carbon credits from CDR projects in 2024 came from a single buyer (Microsoft). AlliedOffsets finds Microsoft dominated H1 2025 market activity.<sup>21</sup> Similarly, the suppliers of CDRs are limited, with AtmosClear (US), Stockholm Exergi (Sweden), and CO280 (Canada) together accounting for 75 percent of all transactions in 2025, all within the biomass carbon removal.<sup>22</sup>

Financing eCDR projects is challenging in ways similar to other types of carbon credit investments, such as delivery risk, offtake risk, policy and regulatory risks (for example, corresponding adjustments), MRV risks, and the underlying developer and associated credit risks. However, eCDR projects have the added risks of new (and often unproven) technologies, very high up-front costs, and long lag times from inception to revenue generation. The biggest barrier to scaling the supply of CDRs is access to finance; a 2024 report indicated that 68 percent of project developers identified this as the top challenge.<sup>23</sup>

In addition to grants and direct government support, a significant source of financing for eCDR projects is advanced purchase commitments from corporations (mainly from Microsoft at this stage). This certainty of revenue streams allows the developers to secure up-front financing based on secured future cashflows. Without these agreements, conventional debt structures, such as bank loans, do not work for eCDR projects due to the high up-front investment costs, long payback periods, and uncertain revenue flows and timing. Unlike BECCS, which generates revenue from the underlying bioenergy asset, direct air capture and mineralization business models rely on continued interest from large tech or

18 Currently, complete IPCC inventory guidelines are only available for BECCS. The IPCC plans provision of guidelines for other eCDR technologies through a dedicated CDR methodology report with conclusion of the seventh assessment cycle in 2027, according to the report of the sixtieth session of the IPCC, <https://www.ipcc.ch/report/2027-ipcc-methodology-report-on-carbon-dioxide-removal-technologies-carbon-capture-utilization-and-storage-for-national-greenhouse-gas-inventories-additional-guidance/>.

19 MSCI Carbon Markets 2024

20 <https://cen.acs.org/environment/greenhouse-gases/Oxy-buys-direct-air-capture/103/web/2025/04>

21 AlliedOffsets. 2025. "CDR: State of the Market (July 2025)." [CDR -State-of-the-Market-July-2025.pdf](#)

22 Ibid.

23 CDR.fyi. 2024. 2024+ Market Outlook Summary Report. [2024+ Market Outlook Summary Report](#).

## Case Studies of eCDR in Emerging Markets

**Kenya:** Located in Kenya's Great Rift Valley, Project Hummingbird is Africa's first commercial direct air capture (DAC) plant, developed by Octavia Carbon in partnership with Cella Mineral Storage. The facility uses 100 DAC machines to capture approximately 1,000 net tons CO<sub>2</sub> per year using geothermal waste heat (providing 80 percent of required energy) to lower operational costs. The project secured US\$5 million in seed funding in late 2024, followed by a US\$10 million round in 2025 led by Lowercarbon Capital, Lateral Frontiers, and E4E Africa. The project had pre-purchase agreements of US\$1.1 million with major buyers, including the Milkywire Climate Transformation Fund (procuring for Klarna) and Terraset. Frontier, a carbon removal consortium backed by large tech companies, has signed two pre-purchase agreements with Cella as of January

2026. The credits are based on the Puro Standard with a 10-year delivery schedule designed to provide predictable cash flow.<sup>26</sup>

**Brazil:** In late 2025, Brazil announced its first industrial-scale BECCS project at a corn-ethanol facility in Lucas do Rio Verde. The facility captures CO<sub>2</sub> generated during the fermentation process of corn-ethanol production and will compress and inject approximately 423,000 tons of CO<sub>2</sub> per year into deep saline formations in the Parecis Basin. The Brazilian Development Bank (BNDES) is providing about US\$71 million in debt funding for the project. Sequestration credits for this project have already been contracted at approximately US\$150 per ton. A key driver of the project is a domestic regulatory mandate requiring oil and gas concessionaires in Brazil to reinvest 1 percent of gross revenue into local R&D and low-carbon technologies.<sup>27</sup>

### Box 1. Case Studies of eCDR in Emerging Markets

other emissions-heavy industries (for example, aviation) in pursuing net zero and other decarbonization goals.

In a 2025 survey report, CDR developers indicated that grants and subsidies are the most widely prioritized financing source (67 percent), and the most prevalent market-based financing forms among suppliers were prepaid offtake agreements (52 percent) and project equity investments (47 percent).<sup>24</sup> Some fossil fuel companies are strategically positioning themselves as suppliers of corporate or project equity in eCDR.

Occidental Petroleum has a subsidiary focused on developing direct air capture hubs in the United States, and through this subsidiary, it acquired a leading direct air capture technology company in 2023.<sup>25</sup>

These financing challenges are exacerbated by the higher country risks in emerging markets, both those perceived by international investors and the real risks associated with macro-financial dynamics. That said, some interesting eCDR deals have been carried out in emerging markets (see Box 1).

24 CDR.fyi. 2025. THE STATE OF DURABLE CDR FINANCING Insights from the CDR.fyi x Planet2050 Survey. <https://www.cdr.fyi/reports/cdr-financing-report.pdf>.

25 Occidental. 2023. "Occidental Enters into Agreement to Acquire Direct Air Capture Technology Innovator Carbon Engineering." Press release, August 15, 2023. <https://www.oxy.com/news/news-releases/occidental-enters-into-agreement-to-acquire-direct-air-capture-technology-innovator-carbon-engineering/>.

26 Octavia Carbon - <https://www.octaviacarbon.com/technology#hummingbird>.

27 <https://carbonherald.com/brazils-bndes-to-invest-71m-in-first-industrial-beccs-project/#:~:text=byViolet%20George,direct%20subtraction%20from%20atmospheric%20levels>

International financial institutions, such as multilateral development banks, as well as national development banks, can play a critical role in supporting the growth of the eCDR sector in emerging markets. These institutions can take risks that investors are not willing to take today, and they can leverage concessional capital to mobilize private sector investors. This can be achieved through the provision of patient capital, including grants, concessional loans, contingent capital, guarantees, and insurance. These institutions can take up-front risks during the 'valley of death' period for eCDR projects, when the technology is being piloted and not generating carbon credit revenues. They can structure blended financing and public-private partnership arrangements. They can also provide floor price guarantees for a portion of the eCDR carbon credits, insure the buyers against government-related risks, provide a liquidity backstop for payment and delivery risks, and provide other risk mitigation tools. Outcome bonds can mobilize private capital markets investors to generate up-front financing as has been demonstrated by other carbon credit-linked transactions, most recently for cook stove projects in Ghana.<sup>28</sup> Other tools include associated technical assistance to suppliers and host country governments, as well as intermediation of eCDR credits with buyers. There are many ways public sector financial institutions can support the nascent eCDR sector and turn it into a scalable way to more quickly and permanently address the climate change challenge.

The World Bank Group's direct engagement with eCDR is still emerging, but the institution has built substantial experience in carbon management and CCUS enabling environments through the World Bank Carbon Capture and Storage (CCS) Trust Fund, which supported client countries between 2009 and 2024 (including capacity building, en-

abling frameworks, and storage resource assessments). This experience underpins complementary work relevant to eCDR (for example, transport and geological storage readiness). A recent example is public Nigerian CO<sub>2</sub> Storage Atlas (March 2025) of the International Finance Corporation (IFC), funded by the World Bank CCS Trust Fund and developed with government counterparts to document prospective CO<sub>2</sub> storage resources and inform CCUS cluster development.<sup>29</sup> In Timor Leste, IFC advised the government on the enabling legal and regulatory environment for a CCS storage hub that would repurpose a depleted gas field that had generated significant royalties while productive.<sup>30</sup>

Work on the transport and storage components of traditional carbon capture value chains can also be applied to eCDR. However, to deploy and scale eCDR in developing countries, international development organizations would need to provide technical preparation, advisory, and capacity building to an even greater extent, given the lower baseline of market and technological readiness.



28 For information about World Bank outcome bonds, see <https://treasury.worldbank.org/en/about/unit/treasury/ibrd/outcome-bonds>.  
29 <https://www.ifc.org/content/dam/ifc/doc/2025/nigerian-co2-storage-atlas.pdf>.  
30 <https://disclosures.ifc.org/project-detail/AS/607385/timor-leste-carbon-capture-storage>.