OVERLOOKED INDUSTRIALISATION OPPORTUNITY?

How the Global South can Leverage Carbon Dioxide Removal (CDR)

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ABSTRACT

Carbon dioxide removal (CDR) is a core component of achieving net-zero, and the only solution we have to address both residual and historical emissions. Since 2018, the sector has expanded rapidly, now exceeding 600 firms, growing by over 200% annually, and surpassing $10 billion in cumulative market value. However, activity remains largely concentrated in advanced economies. This paper examines the potential of the Global South to participate in and benefit from this emerging industry. Developing regions hold around 70-75% of global biomass residues, 65-70% of geological CO_2 storage capacity, and abundant low-cost renewable energy, offering strong conditions for scaling durable CDR approaches such as biochar carbon removal, BECCS, DACCS, and enhanced rock weathering. Under plausible 2050 deployment levels of 1.5-5 $GtCO_2\ yr^{-1}$, the sector could sustain 3-9.5 million jobs and generate $180-600 billion in annual value added by 2050, comparable to major industrial sectors in the Global North. Case studies from Bolivia, Brazil, and Kenya highlight early configurations where CDR combines removals with rural employment, technological learning, and improvements in soil and air quality. As frameworks such as the EU Carbon Removal Certification Framework and the Paris Agreement's Article 6 mature, aligning domestic policy, finance, and governance could enable developing economies to capture a significant share of the market. Positioned as a green window of opportunity, CDR offers a pathway to low-carbon industrialisation that departs from extractive growth models while contributing to durable mitigation, technological upgrading, and poverty alleviation.

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1. Introduction

To achieve net-zero we have to reduce emissions first. However, there will always be residual emissions that cannot be eliminated, and historical emissions which we need to draw down from the atmosphere or they will continue to heat up our planet. Unlike carbon capture and storage (CCS), which prevents new emissions at their source, carbon dioxide removal (CDR) extracts CO_2 from the air and stores it for years to millennia. CDR is the only way of addressing both residual and historical emissions.

CDR has quickly evolved from a scientific concept into a recognisable industrial sector: ever since its scientific genesis in 2018 (IPCC 2018), the sector has grown at over 200% annually, evolving into a nascent multi-billion-euro industry with 600 firms across more than a dozen technological pathways (CDR.fyi, 2025a). Beyond its climate impact, CDR is associated with a range of societal, agricultural, and economic benefits. As a result, many governments around the world are supporting the growth of domestic CDR industries.

However, it is still early days, and "green windows of opportunity" remain for countries seizing this opportunity right now. Prepared in the run-up to COP30 in Belém (November 2025), this paper asks whether this window could deliver broad-based developmental outcomes in the Global South or reinforce economic asymmetries benefitting the Global North[1].

If supported by coherent industrial policy, equitable governance, and clear international rules, we find that CDR in the Global South could generate 3-9.5 million jobs as well as $180-600 billion in annual value added by 2050, while supplying cost-effective removals for Global North buyers - corporates and governments alike.

The paper proceeds in four steps. First, it defines durable CDR and why durability, not just tonnes, underpins integrity and market value. Second, it sets out the development case with quantified employment and output effects under plausible Global South deployment ranges. Third, it grounds the argument in country case studies - Bolivia, Brazil, and Kenya - to illustrate the impact of different ownership structures, capabilities, and policy trajectories. Finally, it offers policy implications for both North and South: industrial tools and governance arrangements. The goal is practical: to show how CDR can become a dual-purpose solution delivering both

[1] In this paper, Global North are high-income, industrialised economies, largely OECD members, characterised by deep capital markets, standard-setting capacity, and growing demand for high-integrity removals. Global South refers to low- and middle-income economies across Africa, Latin America and the Caribbean, and much of Asia. We use these terms as analytical, not geographical, categories: operationally, the "North" approximates IMF advanced economies and World Bank high-income groups, while the "South" aligns with IMF emerging market and developing economies and World Bank low- and middle-income groups (Dados & Connell, 2012; IMF, 2023; World Bank, 2025a). We retain this shorthand because it captures persistent structural asymmetries in finance, technology, and rule-making that are material to CDR market formation and governance. Both labels are heterogeneous and context-dependent; each contains diverse capabilities, constraints, and political economies.

climate outcomes and industrial opportunity, without reproducing old patterns of dependency.

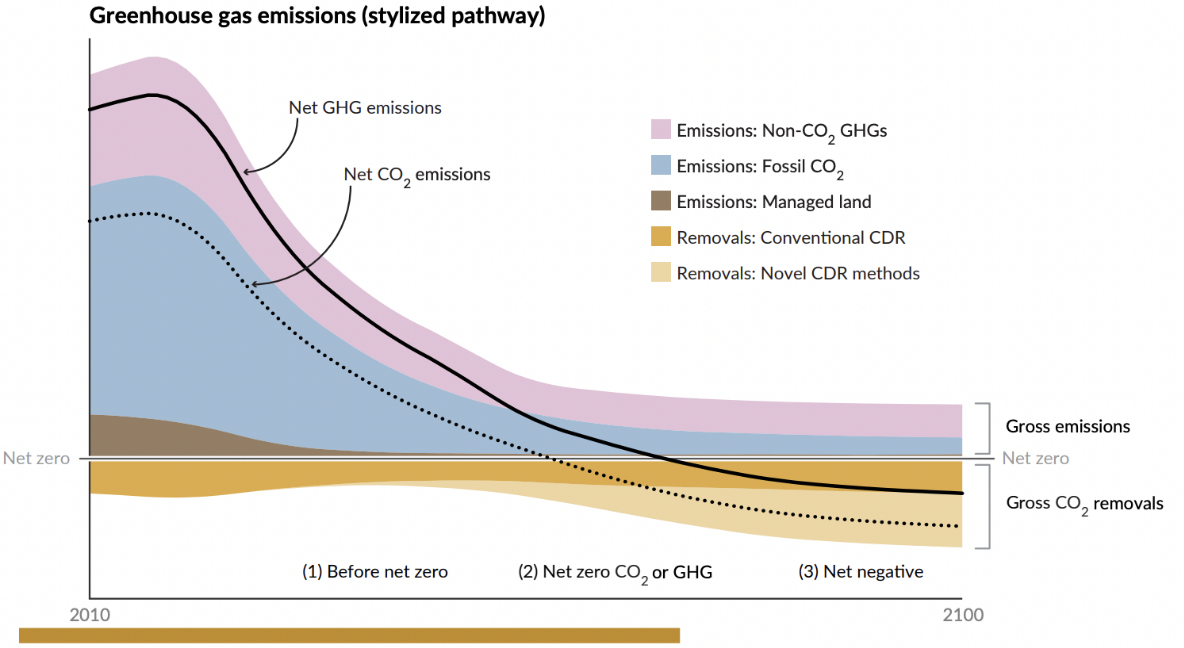

Figure 1.1 *Roles of carbon dioxide removal (CDR) in ambitious mitigation strategies, applicable at national and global levels. Basic emission and removal components of mitigation pathways, and the corresponding trajectories for both net carbon dioxide (CO_2) and greenhouse gas (GHG) emissions. (Adapted from Babiker et al., 2022.)[4]*

Figure 1: CDR in net-zero objectives (State of CDR, 2024)

2. What is Durable CDR and Its Role in Global South Net-zero Strategies

What is CDR and What It Is Not

CDR refers to human activity that captures CO_2 from the atmosphere and stores it for years to millennia in geological, terrestrial, oceanic, or industrial reservoirs (State of CDR, 2024). Understanding what CDR is requires placing it in contrast with conventional mitigation strategies, such as carbon capture and storage (CCS). CCS captures emissions at the point of release, such as flue gases from power plants, and prevents them from entering the atmosphere (IEA, 2024a). By contrast, CDR targets carbon already dispersed in the air, addressing historical as well as residual emissions (Oh, 2025).

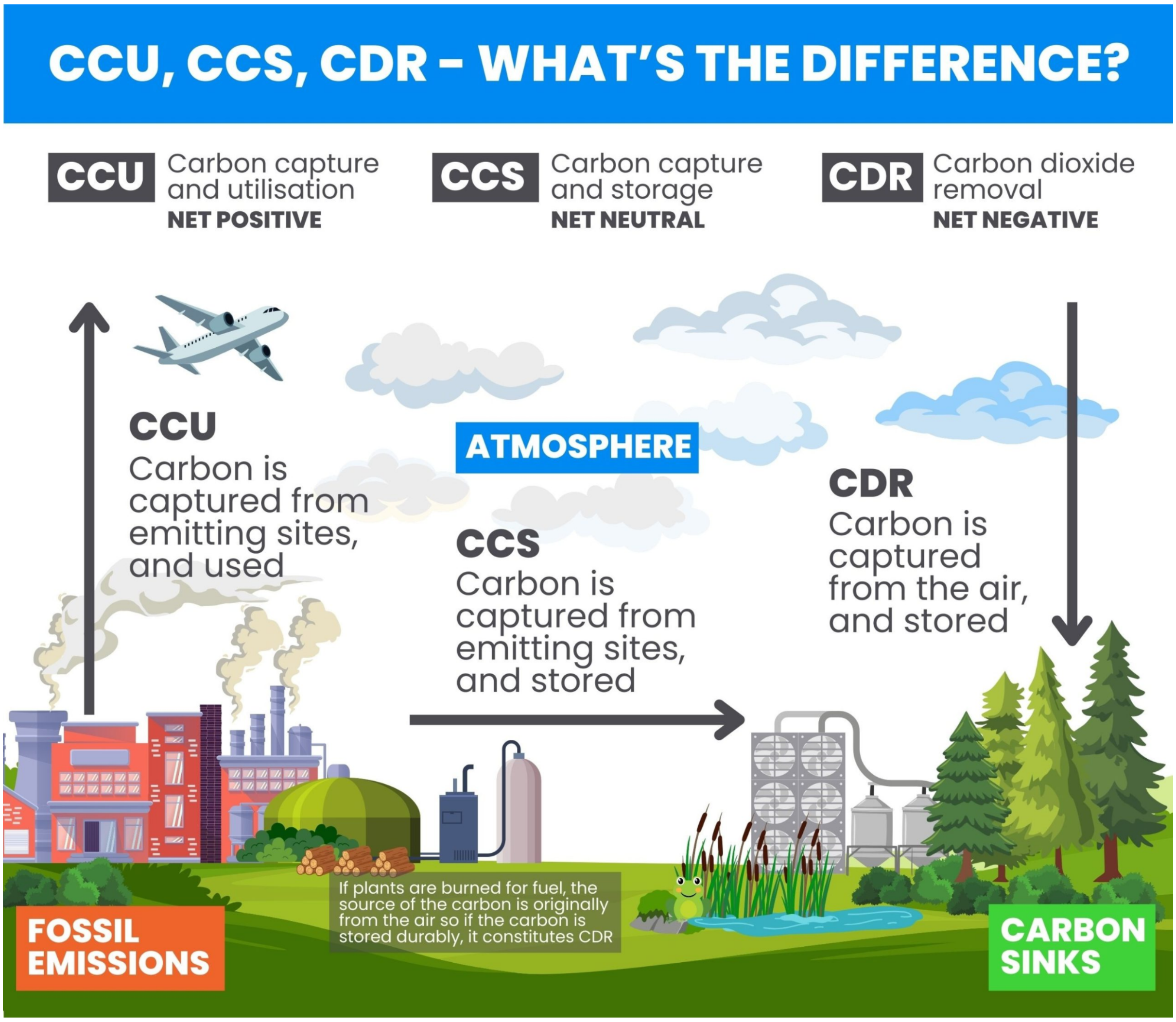

Figure 2: CCU/CCS/CDR (Carbon Gap, 2025a)

There are overlaps between the two domains: geological storage sites used for CCS are also central to some durable CDR methods such as direct air capture and storage (DACCS) or bioenergy with carbon capture and storage (BECCS) (Mintz-Woo & Lane, 2021). Yet these overlaps conceal an essential distinction: CCS is an emissions reduction measure, which lowers the gross volume of emissions released. CDR, on the other hand, generates "negative emissions" by creating a net flux of CO_2 out of the atmosphere, enabling balance in net-zero strategies and eventual net-negativity (IPCC, 2022). Net-zero scenarios require both (IPCC, 2022), but only CDR can neutralise residual and historical emissions.

Market Integrity and the Legacy of Low-Quality Offsets

Public debate on carbon markets is often shaped by the legacy of low-integrity offsetting, which has fostered widespread scepticism about the credibility of carbon credit systems. Investigations into avoided-deforestation projects (REDD+) and other "emissions avoidance" mechanisms have documented systematic over-crediting and weak additionality. The Guardian (2023) found that over 90% of Verra-certified rainforest offsets may not represent genuine emissions reductions, while subsequent analyses (The Guardian, 2024) of BP-owned Finite Carbon's forest projects in the United States revealed credits issued for trees that were never at risk of harvest. Meta-reviews such as Lezak et al. (2025) reach similar conclusions, highlighting structural flaws, uncertain baselines, impermanence, leakage, and double counting, across parts of the voluntary carbon market.

Crucially, these controversies concern emissions avoidance, not carbon removal. Avoidance credits attempt to compensate for emissions by claiming that hypothetical future releases did not occur; they do not physically reduce nor remove atmospheric CO_2. Durable CDR, by contrast, removes CO_2 already in the atmosphere and stores it - measurably - for centuries to millennia in geological, mineral, or stable carbon forms. Its verification is empirical rather than modelled: it rests on observed carbon fluxes, traceable storage pathways, and liability provisions for reversal. This distinction has become central in both scholarship and policy. A growing body of literature argues that the credibility crisis surrounding traditional offsets underscores the need to shift focus toward durable removals, activities with quantifiable storage, long-term permanence, and transparent accounting (Schenuit et al., 2023; Romm; 2025). The recent wave of scandals has therefore not weakened the rationale for CDR, but clarified it: only measurable, durable removals can serve as legitimate instruments within net-zero and compliance frameworks.

Policy frameworks now reflect this shift. The U.S. Treasury's (2024) Principles for Responsible Voluntary Carbon Markets, the EU Carbon Removal Certification Framework (CRCF), and the operationalisation of Article 6.4 of the Paris Agreement establish stricter criteria for additionality, conservative baselines, storage durability, and MRV. Together they define a new, high-integrity carbon credit sector, emerging precisely because older offset models proved inadequate.

Technological overview of CDR

CDR encompasses a wide range of approaches, biological, chemical, and geological, that remove and store atmospheric CO_2 on timescales from years to millennia. From approaches such as afforestation, soil-carbon enhancement, and wetland restoration; mineralisation pathways like and carbon mineral storage; and emerging ocean-based options such as alkalinisation and deep biomass deposition (Whitebeard, 2025).

The approaches with the clearest near-term industrial prospects and evidence for sufficient durability are Biochar carbon removal (BCR), BECCS, DACCS, and enhanced rock weathering (ERW). These four approaches will also be of this paper.

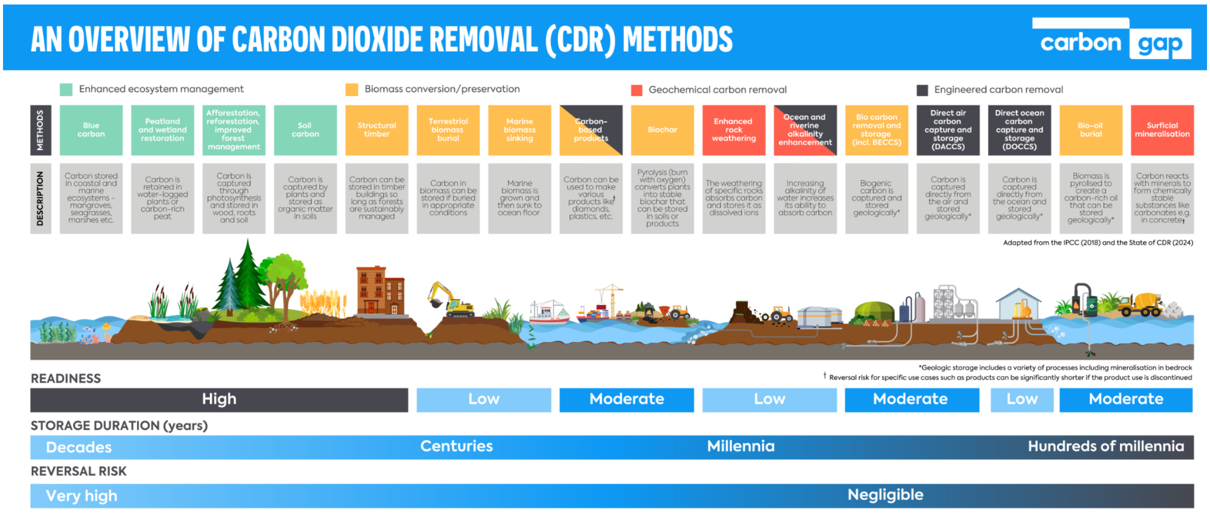

Figure 3: CDR technologies (Carbon Gap, 2025a)

BCR converts agricultural or forestry residues into a stable, carbon-rich solid through pyrolysis, which can be applied to soils or integrated into materials (TRL 8-9). BECCS captures CO_2 released from biomass energy and stores it underground, producing both low-carbon energy and durable removals (TRL 7-9). DACCS chemically extracts CO_2 directly from ambient air for geological storage, offering strong verifiability alongside high energy demand (TRL 6-8). ERW accelerates the natural reaction of silicate minerals with CO_2, usually applied on agricultural land, forming stable carbonates while improving soil fertility (TRL 4-6) (Whitebeard, 2025; Chiaramonti, 2024; Ganeshan, 2023; Bisotti, 2024; Beerling et al. 2018; IPCC, 2022)

These four pathways combine verifiable carbon durability with scalable industrial processes, making them the focus of this paper. Still, the broader CDR landscape remains diverse, as illustrated in Figure 3, spanning biological to engineered methods whose maturity and durability vary widely.

Why Durability Matters

Once the distinction between removal and reduction is made, the question of durability becomes central. Just as the source of CO_2 matters, so too does the time scale of its sequestration. Not all CDRs are equal. The key dividing line is between durable (often called permanent) and temporary CDR.

Temporary CDR, such as afforestation, soil carbon enhancement, and certain ecosystem restoration, stores carbon for years or decades. These approaches deliver essential co-benefits for biodiversity, adaptation, and livelihoods, but their carbon stock remains vulnerable to fires, pests, or land-use change. Such short-lived sequestration may buy time but cannot provide a structural solution to climate stabilisation (Schenuit et al., 2023). It is a complementary tool and temporary removals can validly offset short-lived greenhouse gases (SLGHGs) such as methane and nitrous oxide, whose atmospheric lifetimes are measured in years to decades rather than millennia. More importantly, the scaling potential of temporary CDR is limited. Current land-based removals already reach about 2 $GtCO_2$ per year, and most analyses suggest that sustainable expansion will be small as land competition, water stress, and ecological trade-offs constrain growth (Wang et al., 2025).

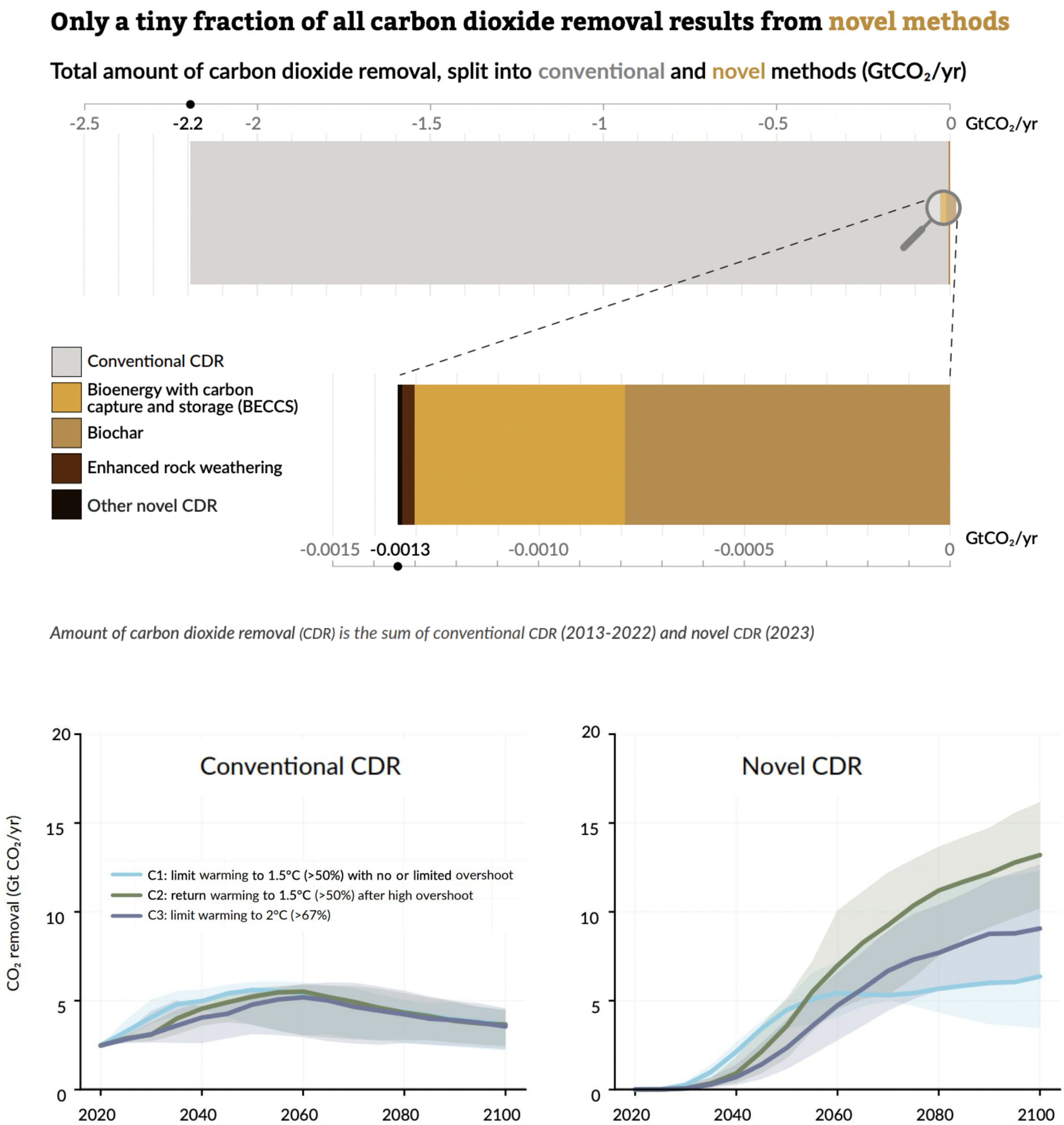

Figure 4: Conventional vs Novel CDR (State of CDR, 2024)

In contrast, durable CDR aims for storage over centuries to millennia, depending on the reservoir. Pathways such as DACCS, BECCS, and ERW offer the highest permanence, with carbon stored for millennia. Industrial BCR can also be durable for centuries to millennia when applied to stable end matrices. Ocean alkalinity enhancement may achieve similar timescales, though its durability remains under evaluation (State of CDR, 2024; Lehmann et al., 2021; Sanei et al., 2024; Azzi et al., 2024). Here lies the credibility test of CDR: if removals are reversed within decades, they cannot be treated as equivalent to fossil emissions that persist for thousands of years (Streck et al., 2025). This is why the so-called "like-for-like" principle - durable removals for long-term, fossil emissions - is increasingly emphasised in climate policy and markets. (Schenuit et al., 2023). Durable CDR today accounts for only a few million tonnes of verified removals annually, but its scalable potential reaches 2-5 Gt CO_2 yr^{-1} by mid-century in most net-zero scenarios (State of CDR, 2024).

Global Market Snapshot

Durable CDR is emerging as a distinct market segment, with the $10 billion mark passed in 2025 (CDR.fyi, 2025b). Transactions and standards are also taking shape, yet current volumes remain far smaller than the multi-gigatonne scale required. As a reminder: between 4.5 and 9 $GtCO_2$ per year of removals will be required by 2050 to remain within 1.5-2 °C pathways (IPCC, 2022).

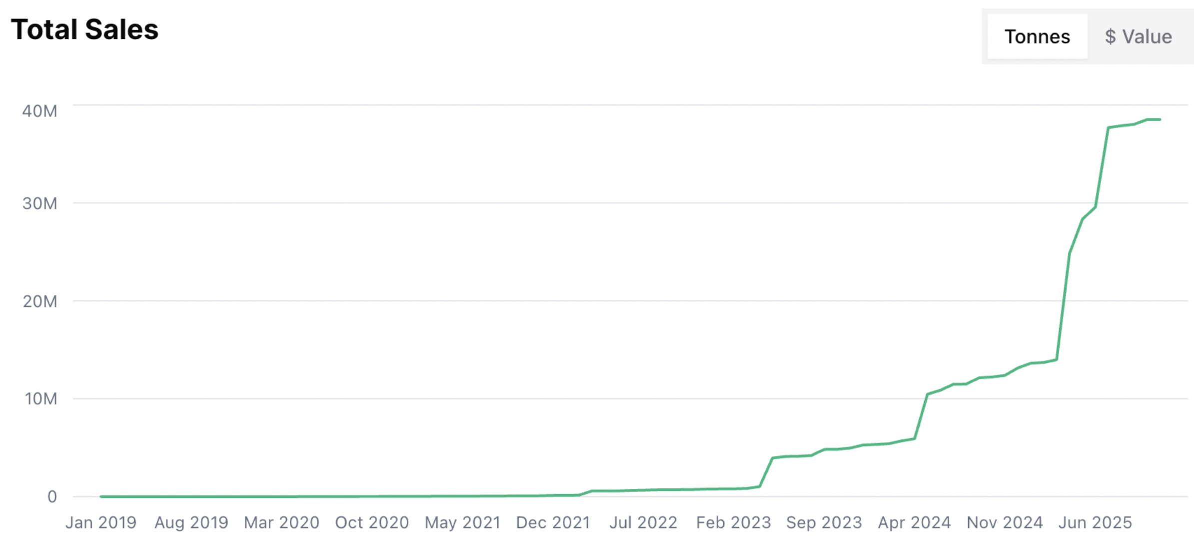

Figure 5: CDR sales (CDR.fyi, 2025b)

The market for CDR spans three emerging arenas: voluntary, compliance, and UN-supervised mechanisms. At present, CDR plays a negligible role in compliance markets, though integration is planned in systems such as the EU ETS and UK ETS post-2030. Under the Paris Agreement's Article 6, UN-supervised frameworks are technically operational to enable future international trade toward NDCs. However, CDR has only been part of a single Article 6.2 agreement and no durable CDR methodologies have been adopted for Article 6.4. A landmark bilateral deal between Switzerland and Norway marked the first cross-border transfer of durable removal credits under Article 6.2, and established a framework for permanent CO_2 storage and ITMO transfers (S&P, 2025a). Consequently, today's CDR activity takes place almost entirely within the voluntary carbon market (VCM), a space historically dominated by avoidance and reduction credits such as renewables and forestry. These legacy segments are now contracting due to credibility concerns (SOVCM, 2025), with rules and corporate demand shifting toward measurable, durable removals. The CDR market only emerged around 2020-2021, yet has since become the fastest-growing segment of the VCM, expanding from roughly 1 $MtCO_2$ of contracted removals in 2022 to nearly 40 $MtCO_2$ by mid-2025, a more than 3,700% increase in three years (CDR.fyi, 2025b), driven by corporate net-zero commitments and the rise of high-integrity certification frameworks.

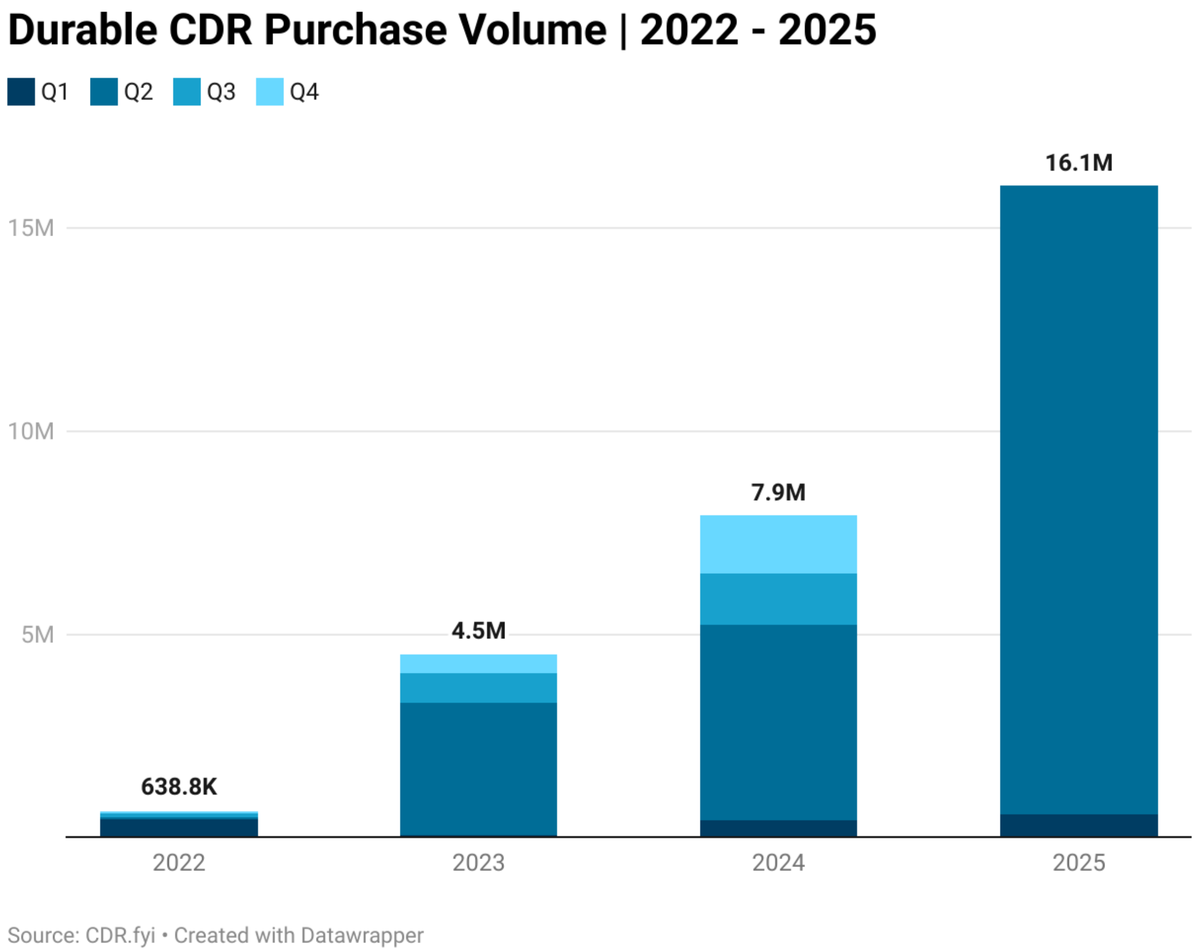

Figure 6: CDR volumes (CDR.fyi, 2025c)

Market projections highlight the scale of this opportunity. By 2030 alone, estimates place the market between $40 and $80 billion, with some projections extending up to $100 billion (BCG, 2024a; McKinsey & Company, 2023; Oliver Wyman, 2024). In 2024, the CDR market grew by 78%, with total contracted volumes reaching nearly 8 million tonnes. At the same time, 2025 has already seen a marked increase: in Q2 alone, 15 million tonnes of durable CDR were contracted, more than in all prior quarters combined (CDR.fyi, 2025b). The buyers on the VCM recently purchased several million tonnes of CDR, now valued in the billions of dollars ($10 billions as of Oct. 2025, CDR.fyi, 2025b). Forecasts suggest a global CDR market worth $517-$1,029 billion[2] annually by 2050, equivalent in size to today's cloud computing industry (BCG, 2024a).

These figures point to a dynamic market with signs of declining technological costs (Abegg et al., 2024), rising demand, and strong regional differentiation. Europe alone may require from 500 (European Commission, 2024a; ESABCC, 2025) to 750 $MtCO_2$/year (BCG, 2024b) of removals by 2050, while individual countries are setting targets in the tens of millions of tonnes. For developing economies with abundant biomass, minerals, or renewable energy, CDR represents not only a climate neutrality need but also a potentially multi-trillion-dollar industrial sector in the making.

Policy Signals

The Global North is already building the industrial and regulatory architecture to scale CDR. In Europe, the Carbon Removal Certification Framework establishes the first EU-wide certification for durable removals, likely to become the gold standard for CDR certification globally (European Commission, 2025a). The EU is increasingly funding CDR R&D and pilots while exploring public procurement of CDR credits. (Carbon Gap, 2025b, European Commission, 2025b). These measures both stimulate demand and prepare the ground for future integration into compliance systems such as the EU ETS (European Commission, 2025c).

At the same time, member state governments are directly investing in their own industries. Germany is planning to spend over $550 million for CDR projects, embedding them in its 2040 climate framework and setting up a dedicated CDR department (BMUKN, 2025). Denmark has committed $1.43 billion of funding for BCR and over $370 million for CCS- based CDR initiatives, awarding multi-year contracts that de-risk early projects and create an investable pipeline (KEFM, 2022, ENS DK, 2025). In the United States, the enhanced 45Q tax credit provides up to $180 per tonne for DACCS with geological storage (IEA, 2024b), a policy that has already underpinned multi-billion-dollar commitments from U.S. firms, while several states such as California and New York are layering additional incentives on top (GOV.CA 2022; WRI, 2024). Sweden has made BECCS central to its 2045 net-zero strategy, with the Swedish Energy Agency running reverse auctions under Klimatklivet and Industriklivet worth up to $3.63 billion to procure verified removals between 2026 and 2040 (European Commission, 2024b). The United Kingdom is advancing similar market design through its GGR Business Models and UK ETS Review, preparing to

[2] €1 = $1.10

integrate durable removals, initially BECCS and DACCS, into compliance markets after 2030 while also investing billions via carbon contracts for difference and industrial cluster pilots (GOV.UK, 2025). Canada, meanwhile, combines a federal 60% CCUS Investment Tax Credit allocating $2.3 billion over five years and potentially up to $5.5 billion by 2030 (CRA, 2024).

The pattern is apparent: the Global North is not only creating the standards and compliance frameworks that will govern future markets, but is also financing its own industrial base, supporting domestic companies to capture early market share. This dual approach of stimulating demand through certification and regulation, while de-risking supply through subsidies and auctions, mirrors the pathways that enabled renewables to scale. It positions advanced economies as the first movers in a sector that could reach hundreds of billions annually by mid-century.

Taking the Industrial Lens

The trajectory in the Global North shows that CDR functions not only as a mitigation instrument but as a lever of green industrial policy. Comparable efforts in the Global South remain limited. Research on green catch-up stresses that environmental sectors differ from past technological paradigms: they are mission-driven, policy-intensive, and globally diffused (Lema, Fu and Rabellotti, 2020).

Unlike the spontaneous demand dynamics that characterised earlier industrial expansions, today's green economy is deliberately engineered through institutionally designed markets, performance standards, subsidies, certification systems, and public procurement. These mechanisms do not merely correct market failures; they construct new markets for environmental value where none previously existed. Durable CDR, grounded in liability rules, certification methodologies, and public support schemes, fits squarely within this design economy. It is emerging not as a by-product of private incentives but as a policy-built sector of structural transformation, redefining how industrial growth and climate mitigation intersect.

Historical precedents from the Global South illustrate how deliberate industrial construction has enabled latecomer economies to capture value in emerging sectors.. Brazil's ethanol programme in the 1970s-80s turned a sugar surplus into a world biofuel industry through state mandates and flex-fuel innovation (Goldemberg, 2006). Kenya leveraged its geothermal resource to build a competitive electricity base via concessional finance and public-utility coordination (Carnegie Endowment, 2025). Solar photovoltaics, once a niche technology, scaled globally within two decades through European feed-in tariffs, Chinese industrial policy, and cumulative learning effects (Wen et al., 2021). In every case, states manufactured demand and enabled technological learning, conditions now required for CDR to evolve from pilots to industry.

Green windows of opportunity (GWOs) are "temporary, but favourable circumstances for long-run latecomer catch-up" opened by shifts in technologies, markets and institutions; whether countries benefit depends on firm policy responses. Technology creates the window; coordinated state intervention and capability building determine if it is seized. (Lema, Fu and Rabellotti, 2020). Demand creation and capability building must be synchronised if latecomers are to capture the benefits of green transitions. Otherwise, countries fall into market traps (capturing demand volumes without upgrading technological capabilities) or capability traps (building know-how without viable markets).

Renewable energy illustrates this: European feed-in tariffs initially created both demand and domestic industrial capacity, particularly in wind and solar manufacturing. Yet when global competition intensified, Europe's support frameworks fragmented, while China's industrial policy proved far more sustained and coordinated, enabling it to capture production leadership (Bian et al., 2024; Wen et al., 2021). CDR shows a similar asymmetry today: demand is being constructed primarily in the Global North through the VCM, public procurement and subsidy schemes, but the Global South's ability to build matching technological and regulatory capacity will determine whether it can capture emerging value or remain confined to the extractive tiers of the carbon removal economy: supplying biomass, land, and storage while others control technology, certification, and finance.

A second perspective stresses technological appropriateness. "Appropriate technology" aligns with local resource and institutional contexts (Fu and Shi, 2022). Latecomer industrialisation is most effective when new technologies align with local resource endowments, labour markets, and institutional capacities. This applies directly to CDR: BCR suits biomass-rich, labour-intensive economies (USDA, 2021); BECCS aligns with regions combining biomass and storage capacity (Freer et al., 2022); ERW depends on mineral endowments and logistics (Oppon et al., 2024); DACCS thrives where renewables and storage co-locate (Boerst et al., 2024). This diversity enables differentiated industrialisation rather than a uniform model. Countries can identify and scale the option most suited to their own context.

Finally, structural analyses of globalisation highlight urgency. Digitalisation and automation are closing the traditional export-led path to industrialisation (Fu, 2024). Green sectors, by contrast, remain labour- and resource-relevant, policy-intensive, and globally tradable, and thus constitute one of the few viable pathways (Lema, Fu and Rabellotti, 2020). Durable CDR exemplifies such an opportunity: it is underpinned by policy-driven demand and emerging industrial policy in the Global North, yet its long-term scalability depends on resource access and production capacity concentrated in the Global South. Whether Southern economies can convert these endowments into technological and industrial capability before Northern incumbents consolidate the field will determine the geography of value creation in this new sector.

Together, the frameworks of GWOs, technology appropriateness, and global restructuring show that the development case for CDR is both plausible and time-critical. The Global North is already building the market; the South's challenge is to secure a share of the industrial and economic gains while the window remains open.

3. The Development Case: What CDR Could Bring

Potential Benefits for the Global North

The economic potential of CDR is already being mapped out in detail for advanced economies. For the European Union, Boston Consulting Group (BCG; 2024b) and the German Association for Negative Emissions (DVNE) estimate that portfolios consistent with limiting warming to 1.5-2 °C could require 0.9-1.9 $GtCO_2$ of removals by 2050. Such deployment would support 335,000-670,000 jobs across direct, indirect, and induced categories, even in high-productivity labour markets. The associated sector turnover is projected at $121-$248 billion annually, equating to roughly $130 per tonne of CO_2 removed (BCG/DVNE, 2024b).

National-level studies reinforce this picture. By 2050, BCG and AFEN project that in France, could remove 185-365 $MtCO_2$, sustaining 65,000-130,000 jobs and generating $27.5-55 billion in annual revenues (BCG/AFEN, 2025) In Germany, BCG and DVNE estimate that 74-131 $MtCO_2$ of removal capacity could support 66,000-155,000 jobs and $14-$33 billion in yearly economic value (BCG/DVNE, 2024b). Similarly, in the United States, Rhodium Group finds that achieving 100 $MtCO_2$ of durable removals could sustain 95,000-130,000 jobs, roughly two-thirds of them permanent operational roles (Rhodium Group, 2025a). These figures are indicative: employment and value added will depend on technology maturity, scale, and deployment models. Assuming learning trajectories similar to other green sectors, productivity gains will gradually reduce labour intensity. For context, the EU environmental goods and services sector generated ~€538 billion of GVA (EEA; 2025) and ~6.7 million FTE in 2022 (European Commission, 2025d) (~12,450 jobs per € billion), whereas the BCG/DVNE projections imply ~1,350-5,540 jobs per $ billion. This lower employment intensity is consistent with CDR's higher capital requirements but still indicates a sector of substantial macro-economic relevance when scaled to the projected market volumes.

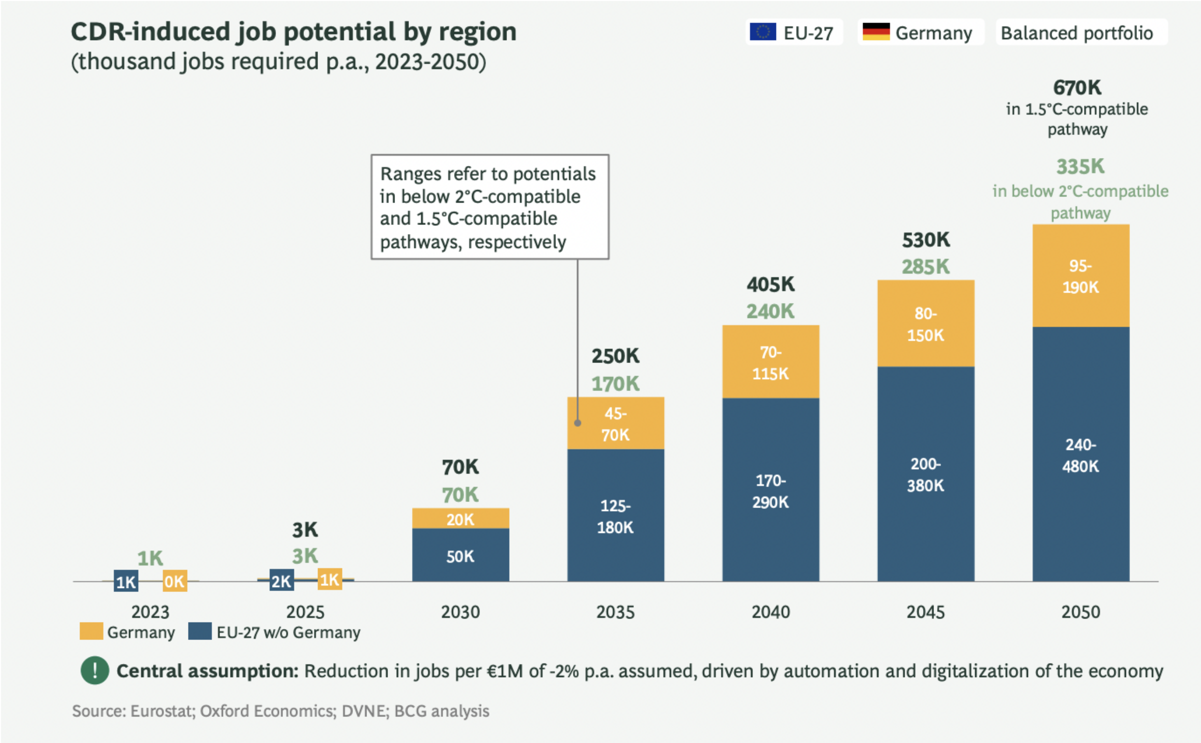

Figure 7: EU CDR jobs 2023-2050 (BCG/DVNE, 2024b)

In other words, for the Global North, the case for CDR as a source of jobs and economic value is starting to be quantified, modelled, supported by policy-makers and embedded in forward-looking industrial strategies. Advanced economies are positioning themselves to capture the benefits of a market expected to reach hundreds of billions annually by mid-century.

But this raises a critical question: why should these benefits be confined to the Global North? The same structural opportunities (new industries, rural employment, value-added sectors) are no less relevant, and in many cases even more pronounced, in the Global South. Indeed, resource endowments and labour intensities suggest that developing economies are especially well positioned to deliver removals at scale.

The Global South's Comparative Advantage

CDR could become a multi-billion dollar export industry in the Global South, a vector of growth generating millions of jobs. Across Latin America, Africa, and Asia, resources align directly with the physical requirements of durable CDR.

The Global South concentrates most of the world's agricultural biomass residues, a necessary feedstock for several CDR technologies such as BCR or BECCs, due to its prevalence in residue-intensive crops and processing industries. Total residues exceed 5.2 gigatonnes per year, of which about 3.7-4.0 gigatonnes (≈70-75%) are generated in developing regions (Sileshi et al., 2025). These quantities are likely to rise as global crop production expands by 30-50% by 2050, implying a comparable increase in residue generation (FAO, 2012; van Dijk et al., 2021) (5-6 Gt of biomass represents 2-6 Gt of CDR; Shahbaz M. et al., 2021; Woolf D. et al., 2021). Tropical and subtropical forests account for over 55% of global forest biomass carbon stocks, offering substantial potential for sustainably sourced woody residues (Mills et al., 2023).

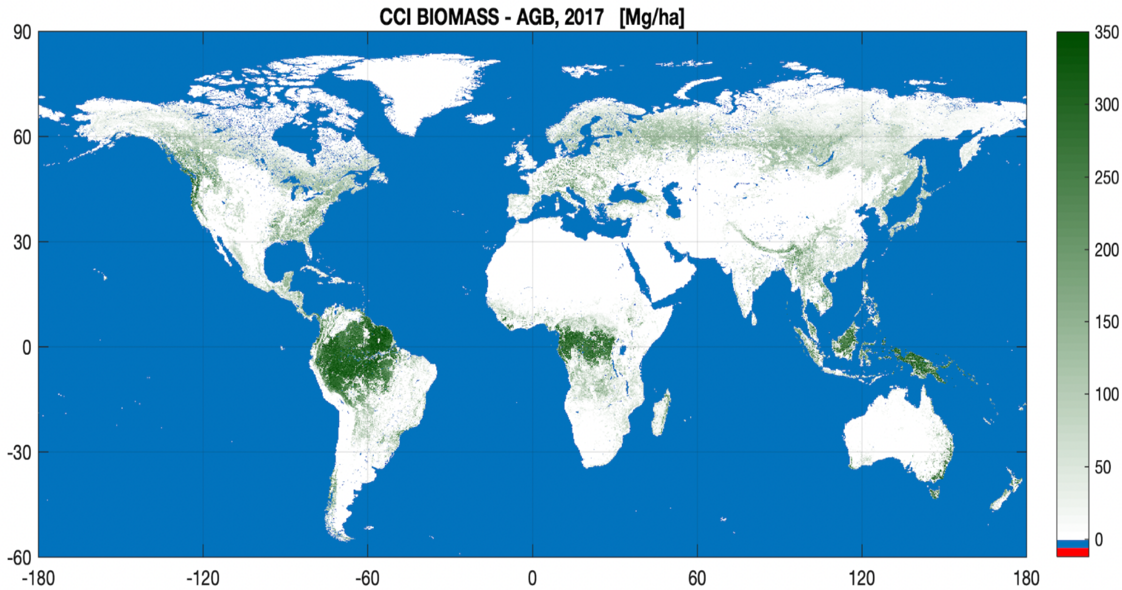

Figure 8: World biomass (ESA, 2019)

Energy-intensive removals like DACCS also find favourable conditions in the Global South. Beyond biomass, the Global South holds massive under-utilised renewable energy endowments. Africa alone has 60% of the world's premium solar resources but <1% of solar deployment (IEA, 2022). And the region is still getting under 3% of global clean energy finance. Kenya already operates a 90% renewable grid, nearly half geothermal (IEA, 2024c), while Chile and India have repeatedly set global records for low-cost solar electricity ($10-$27/MWh) (IEA, 2017, Mercom, 2020). These examples show that, with adequate investment, the Global South could power energy-intensive CDR at competitive costs while driving its own industrial decarbonisation. Additionally, for CCS-based CDR, the Global South holds roughly 1,800-2,000 Gt CO_2 of the world's 2,700 Gt CO_2 geological storage potential, equivalent to roughly 65-70% of global capacity (Gidden, 2025).

Finally, tropical and subtropical regions hold vast silicate formations which position the Global South for EW. It combines abundant basaltic resources (notably in India, East Africa, and Latin America) with warm, humid, and acidic soil conditions that accelerate mineral dissolution (IGSD, 2023, Edwards, 2017). Abundant biomass, minerals, and renewable power make the Global South structurally important to scaling durable CDR.

Employment and Economic Effects of CDR in the Global South

Beyond the clear resource endowments in the Global South, it is crucial to understand the wider impacts of developing large-scale CDR industries. We proceed in four steps: (1) evaluate plausible Global South CDR volumes (2) establish a baseline employment intensity in advanced economies, and adjust for labour intensities in developing countries, (3) scale employment against removal volumes, and (4) translate these into economic impacts using cost-based unit values, gross value added (GVA) shares, and multipliers for spillovers.

CDR deployment volumes in the Global South

There is no single agreed estimate of the Global South's mid-century CDR potential, but three lines of evidence suggest a wide 1.5-5 $GtCO_2$/yr range by 2050. Proportional allocation methods, assuming today's ~45% share of global removals is maintained, yield this range when applied to expected global needs (Ranevska, 2025). Bottom-up technology studies highlight contributions from BCR, BECCS, EW, and DACCS, with indicative totals in the 3-7 Gt range, though overlaps limit simple addition[3]. Finally, integrated assessment modelling (Ampah et al., 2025[4]) finds the Global South could supply ~5 Gt through CDR credit exports by 2050-2060. The wide but plausible range of **1.5-5 $GtCO_2$/yr** provides the volume basis for the analysis of this paper.

[3] Bottom-up check: Enhanced rock weathering (ERW): Beerling et al. (2020) estimate that China, India, Brazil, Indonesia and Mexico together could deliver ~0.6-1.3 $GtCO_2$/yr depending on global deployment levels (Beerling et al., 2020). Biochar Carbon Removal: Deng et al. (2024) find a potential of up to 0.92 $GtCO_2$/yr in China (Deng et al. 2024), while Lefebvre et al. (2023) reports 1.5 $GtCO_2e$ per year for Global South countries (~0.47 $GtCO_2$/yr in China, ~0.30 $GtCO_2$/yr in Brazil and ~0.23 $GtCO_2$/yr in India, giving a subtotal of ~1.0-1.5 $GtCO_2$/yr. BECCS: No Global South estimate exists, however a Chinese national energy systems study projects 0.5-1 $GtCO_2$/yr by 2050 depending on scenario (Huang et al. 2020 or Xu et al. 2024), while Brazilian sector analyses show 0.03-0.25 $GtCO_2$/yr potential from sugarcane ethanol and biomass (Moreira et al. 2016 and other countries around a few $MtCO_2$/y (such as Thailand or Indonesia; Suwannakarn and Salam, 2024; Kraxner et al., 2024), suggesting a 0.5-2 $GtCO_2$/yr potential (with global sustainable limits at around 3 $GtCO_2$/yr; Deprez et al., 2024). DACCS: Fuhrman et al. (2021) forecast 1.6 $GtCO_2$/yr in China whereas Breyer et al. (2019) model a system for the Maghreb capable of ~1 $GtCO_2$/yr by 2050 (Breyer et al. 2019) and Qiu et al. 2024, 0.2-0.3 $GtCO_2$/yr in KSA,. Together, this bottom-up subtotal yields roughly 3-7 $GtCO_2$ per year by 2050 for the Global South. This figure is uncertain: it omits several regions and options (such as marine CDR), and most national or technology estimates assume independent scaling. In reality, technologies will compete for shared feedstocks, land, energy, and storage, and countries for market share, so even the lower bound might overstate achievable potential.

[4] Pre-print at the time of writing.

Employment intensity in advanced economies and labour intensity in the Global South

Across studies for France, Germany, the United States, and the EU-27, the relationship between CDR deployment and gross employment converges at roughly 700 permanent jobs per $MtCO_2$ (within a range of 350-1,000). Including temporary construction and investment phases raises this to about 1,000 jobs per $MtCO_2$ in total.[5] This provides a pragmatic baseline against which Global South adjustments can be made.

Evidence consistently shows that green industries in Global South economies are more labour-intensive than in the Global North. Utility-scale solar plants in Europe typically generate only 2-3 direct jobs per MW, while distributed PV in countries such as India or Kenya creates 15-20 jobs (IEA PVPS, 2024). Wind energy job intensity in developing economies is roughly 2-10× higher than in the OECD: Brazil averages 13.5 job-years/MW and South Africa 6.5, versus 1-3 in advanced economies (Aldieri et al., 2020). Bioenergy shows even larger gaps, where employment per unit of output reaches 2-12× OECD levels, with 81 jobs/PJ in Latin America, 60-90 in China and India, and up to 387 in Sub-Saharan Africa, compared to 30-32 in OECD supply chains (Skeer, 2016; Rutovitz et al., 2015).

Historical data, however, reflect conditions of the 2010s, when productivity gaps were wider. More systematic modelling by Ram, Aghahosseini and Breyer (2020) projects that even by 2050, the Global South will maintain around 1.9 times higher direct employment intensity than advanced economies. Applying this conservative

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[5] To derive a clean rule of thumb, we align national and regional studies using consistent methodological assumptions. AFEN/BCG (France) and BCG/DVNE (Germany) report steady-state gross sectoral employment, covering direct and indirect jobs within the CDR value chain but excluding short-term construction and financing. DVNE's EU-27 roll-up follows the same convention, expressing gross employment captured domestically. In contrast, the Rhodium Group (U.S.) applies a bottom-up IMPLAN input-output model and explicitly distinguishes between ongoing operations and maintenance (≈ two-thirds) and temporary construction (≈ one-third). Using these sources, we take BCG's results for France and Germany under both temperature-consistent pathways (≤2 °C and 1.5 °C) and align 2050 gross jobs with the corresponding CDR volumes (BCG's balanced method mix with a built-in −2% p.a. productivity drift). For the EU-27, a balanced portfolio scenario implies 0.9 $GtCO_2$ of removals supporting 335,000 jobs (≈372 jobs / $MtCO_2$), and a high-volume case of 1.9 $GtCO_2$ linked to 670,000 jobs (≈353 jobs / $MtCO_2$). In France, the scenarios show 185 $MtCO_2$ with 65,000 jobs (≈351 jobs / $MtCO_2$) and 365 $MtCO_2$ with 130,000 jobs (≈356 jobs / $MtCO_2$). These values converge around ≈360 jobs / $MtCO_2$ across geographies and scenarios, representing steady-state, direct + indirect employment excluding construction. The United States, on a comparable construction-excluded basis, yields ≈630-870 permanent jobs / $MtCO_2$, while France, Germany, and the EU-27 cluster between ≈350-1,000 jobs / $MtCO_2$. Harmonising these gives a consolidated range of ≈350-1,000 permanent jobs per $MtCO_2$ across advanced economies. Re-including short-term construction using Rhodium's one-third share (i.e., permanent ≈ ⅔ of total) raises the full employment range to roughly ≈525-1 500 jobs per $MtCO_2$. This value is adopted as a baseline for the employment intensity of CDR in advanced economies. This includes indirect jobs, UNIDO (2025) 's analysis of manufacturing sectors demonstrates that each direct job generates an additional 2.2 indirect and induced jobs, producing a total employment effect 3.2 times higher than direct employment alone. Applying this multiplier to the harmonised range of ≈350-1,000 gross jobs per $MtCO_2$ yields an estimated ≈110-310 direct jobs per $MtCO_2$ (central value ≈225), representing the steady-state operational workforce directly employed within durable CDR industries.

multiplier to the advanced-economy benchmark of around 700 permanent jobs per $MtCO_2$ yields approximately 1,300 permanent jobs per $MtCO_2$. Including temporary construction and investment phases raises this figure to roughly 1,900 gross jobs per $MtCO_2$ for the Global South. This conservative adjustment accounts for expected productivity convergence while recognising persistent structural differences which are likely to persist until 2050.

Economic impact of CDR deployment

Across the EU-27, the estimated value of a tonne of CO_2 removed in 2050 is ~$130[6]. To value economic output, we derive an average unit value from BCG's European scenarios. This figure is adopted for calculations in the Global South.

Direct sector revenue is then adjusted to net economic contribution using gross value added (GVA) shares. Studies of renewable and environmental manufacturing industries in countries such as Mexico, Rwanda, Indonesia and South Africa suggest a 35-55% GVA share, implying $53-$66 per tonne of CO_2 removed (GGGI, 2020). To reflect spillovers into construction, logistics and services, we apply an economy-wide multiplier of 2, consistent with input-output studies of developing economies (Jones, 2011; Gabriel et al., 2020)[7]. The combined effect lifts the economy-wide impact to $99-$143 per tonne of CO_2 removed.

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[6] We derive a portfolio-average unit value by dividing BCG's cost-based economic potential by the associated 2050 removal volumes. For the EU-27, an economic potential of $120 -245 billion at 0.9 -1.9 gigatonnes of removals implies a value of about $128 -132 per tonne of CO_2. For France, an economic potential of $27 -54 billion at 185 -365 million tonnes of removals implies a value of about $146 -149 per tonne of CO_2. On this basis we adopt a working unit value of $130 per tonne of CO_2 for subsequent calculations, aligned with the EU-27 range.

[7] We apply a direct gross value added (GVA) share of 35-55%, consistent with studies of green industries in the Global South. For example, renewable-energy deployment in Mexico (~45%), Rwanda (~46-49%), and Indonesia (~38-49%) falls squarely in this corridor (GGGI, 2020), while environmental manufacturing in South Africa's REIPPPP programme has achieved local content of 44-54% (Eberhard et al., 2024). On this basis, a working unit value of $130/t of gross sector revenue corresponds to about $53 -$66 per tonne of direct GVA. To capture spillovers into construction, logistics and services, we then apply an economy-wide multiplier of 2 (range 1.6-2.3), consistent with cross-country input-output studies for developing economies (Jones 2011 finds 2.5 for China and 1.81 for Brazil across 35 countries, while Gabriel et al. find multipliers of 2.8 for China, 1.6 for India, and 1.8 for Brazil, with an average of 1.9 for developing countries, Jones, 2011; Gabriel et al., 2020), which lifts the economy-wide impact to roughly $99 -$143 /tCO_2.

Results

Table 1. Employment and output potential from CDR in the Global South by 2050

Global South CDR volume ($GtCO_2/yr$)	Permanent jobs per $MtCO_2/yr$ (total)	Gross jobs per $MtCO_2/yr$ (total)	Permanent jobs (million)	Gross jobs (million)	Direct Revenue ($bn/yr)	Economy-wide GVA ($bn/yr)
1.5	1,300 (650-1,900)	1,900 (1000-2,250)	2.0 (1.0-2.9)	2.9 (1.5-3.4)	195	182 (149-215)
3	1,300 (650-1,900)	1,900 (1000-2,250)	3.9 (2.0-5.7)	5.7 (3.0-6.8)	390	363 (297-429)
5	1,300 (650-1,900)	1,900 (1000-2,250)	6.5 (3.3-9.5)	9.5 (5.0-11.3)	650	605 (495-715)

Under plausible deployment levels, CDR could become a notable source of employment and output in the Global South. At 3 $GtCO_2$ per year, the sector could support about 3.9 million permanent jobs, 5.7 including temporary jobs and contribute $363 billion in annual economy-wide GVA. At 5 $GtCO_2$, these figures rise to 6.5 million permanent jobs, 9.5 million including temporary and $605 billion, while even the lower bound of 1.5 $GtCO_2$ yields over two million permanent jobs and ~$182 billion in value. By comparison, the automotive sector supports over 13 million jobs in the EU (direct + indirect; ACEA, 2024) and contributes $165-$220 billion in GVA (Eurostat, 2024), while in the U.S. it supports nearly 11 million jobs and $450 billion in value added (AAI, 2025 ; Harp and Prasad, 2024). Thus a mature CDR industry supporting ~5-10 million jobs and $500+ billion value could rival a major industrial sector in the Global North.

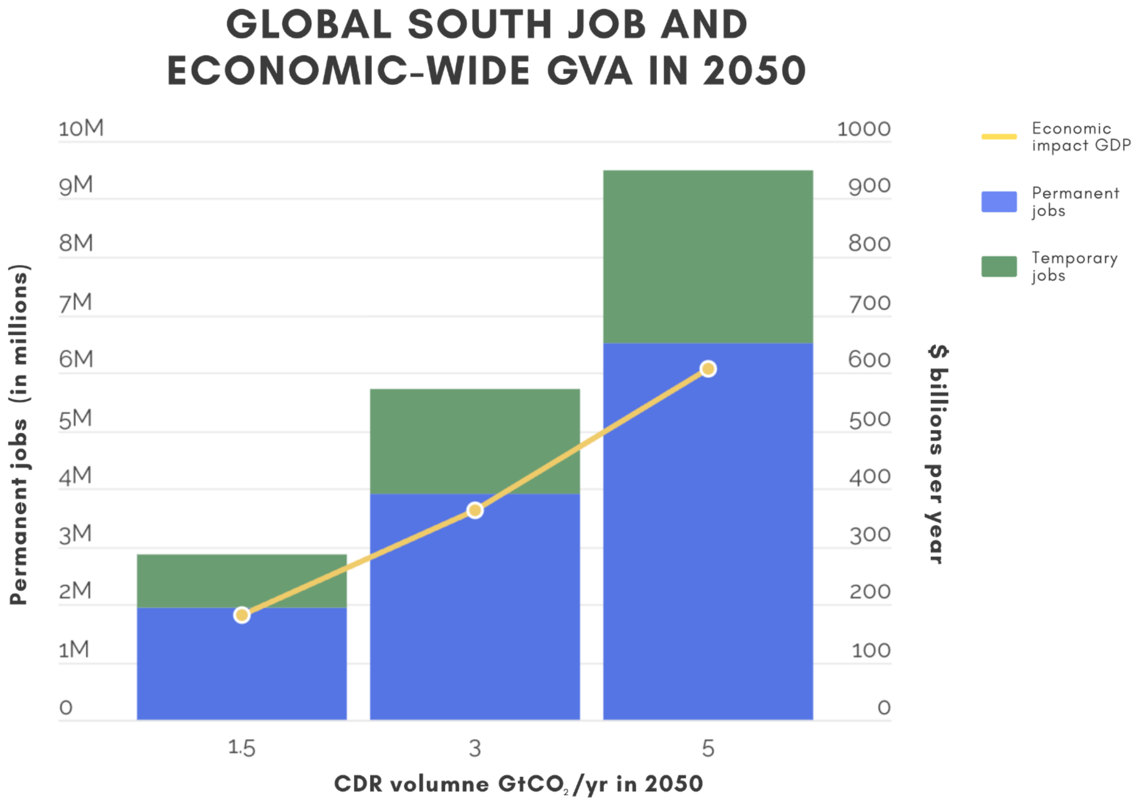
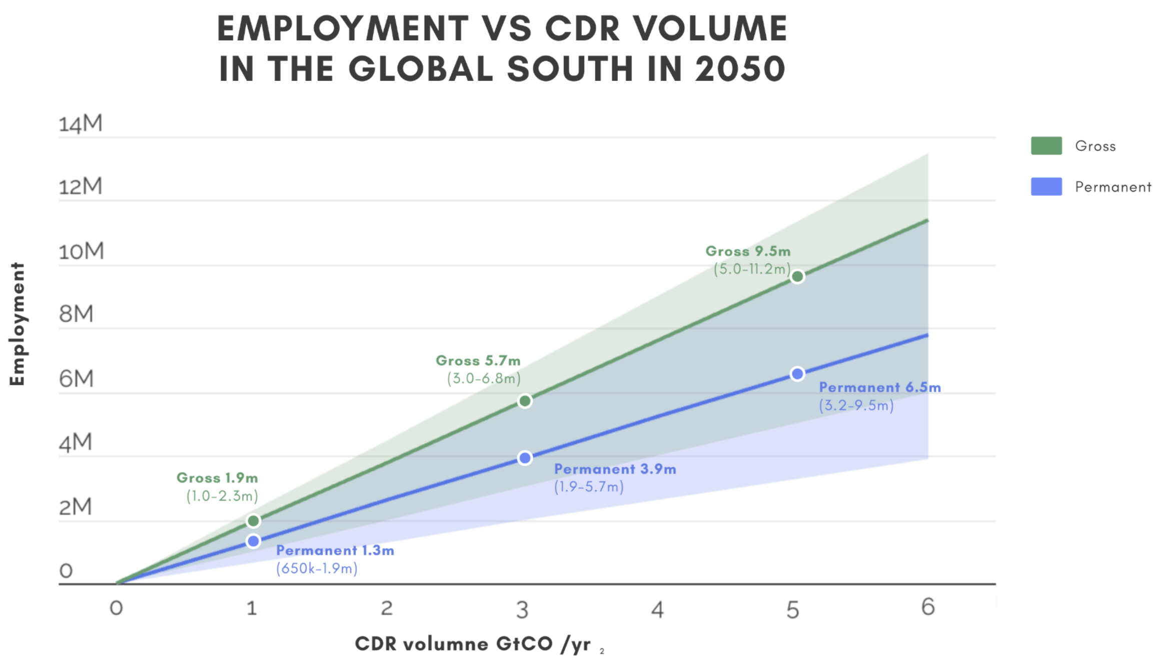


Figure 9: CDR job and economic impact in the Global South in 2050



Notes: Permanent central = 1,300 jobs MtCO2 range (650-1,900). Gross central = 1,900 jobs/Mt (range 1,000-2,250). Jobs scale linearly with volume.

Figure 10: CDR job creation in the Global South in 2050

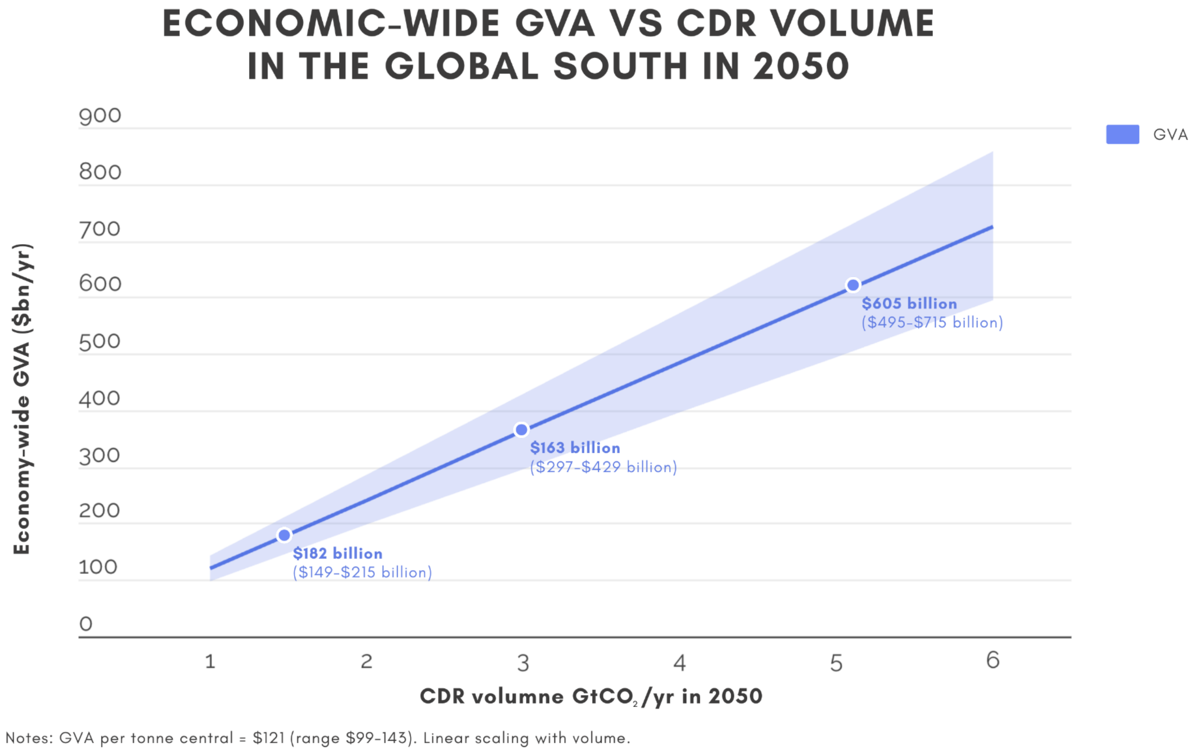


Figure 11: CDR economic impact in the Global South in 2050

These estimates underscore that when labour intensities are adjusted for developing-country conditions, the employment potential of CDR industries becomes considerable. CDR is not only a tool of climate mitigation but also a driver of industrialisation and economic transformation.

Comparative studies reinforce this conclusion. Ampah et al. (2025) estimate that international CDR trade could create 17 million jobs and $3.1 trillion in financial transfers by 2060 at a scale of 5 $GtCO_2$ per year, far above the conservative multipliers used here. While such figures are sensitive to assumptions about technology choice, cost curves and international governance, they indicate the magnitude of opportunity if the Global South can position itselves as an exporter of CDR.

The strategic implication is that CDR represents a rare intersection of climate responsibility and industrial opportunity. For the Global South, developing CDR industries could provide millions of skilled, higher-productivity, higher-pay jobs, attract international capital through carbon markets, and contribute to structural transformation of economies currently dependent on commodity exports. For the Global North, it underscores the importance of building frameworks that allow credible, large-scale procurement of removals from developing countries while ensuring safeguards around land, biomass, and community rights.

CDR Labour Dynamics: Beyond Jobs and GDP, a Poverty Reduction Tool

The development case for CDR in the Global South is not limited to aggregate measures of employment or GDP. Its greatest transformative potential lies in where and how jobs are created. Poverty in developing countries is disproportionately rural: in Sub-Saharan Africa and South Asia, around 46% of rural populations live below national poverty lines, compared to ~20% in urban areas (World Bank, 2024). Africa, the world's youngest continent, will add over half a billion people to its labour force by 2050, most of them in rural areas, creating an urgent need for productive, locally anchored employment (UNDP, 2024;OECD, 2024). These same regions also hold abundant biomass residues and young, under-employed workforces.

Durable CDR is, in essence, a diffuse resource: many small nodes of activity across rural economies, rather than a single high-rent extraction point. Its feedstocks and application sites are inherently scattered, as 4 in 5 farms in the Global South are under two hectares, anchoring production close to the land (Lowder et al., 2021). By leveraging abundant residues and a youthful workforce, it could help narrow spatial inequality and build resilient, locally rooted industries across the Global South.

Climate and Environmental Co-Benefits

CDR industries deliver substantial environmental, agricultural, and societal co-benefits, of high value in the Global South. BCR and BECCS both can address a critical waste-management challenge by converting agricultural residues and even sewage sludge into useful products rather than pollutants. Together, they can help eliminate open-field burning, a major source of rural air pollution (43% of chronic respiratory disease deaths and 17% of deaths from lung infections; WHO, 2024) and wildfire risk, while stabilising carbon and generating value from biomass. Converting residues such as rice straw into biochar reduces lifecycle emissions by 14-26% and cuts methane from manure composting by up to 79% (Patel er al., 2023, Harrison et al., 2022). Biochar has been shown to improve soil function: recent and past meta-analyses report 5-51% yield gains (Jiang, et al., 2024; Li et al., 2024) and up to 25.6% higher water retention in coarse soils (Wei et al., 2023), while reducing heavy metals like lead and cadmium by about 40%, lowering human health risks by 30% (Chen et al., 2018). Additionally, BECCS enhances rural resilience by turning dispersed residues into firm, low-carbon power while capturing CO_2 at source (Moreira et al., 2016).

ERW can strengthen soil health and resilience. Applying finely ground basalt or silicate rock to farmland can raise soil pH by 0.2-1.2 units and supplies calcium, magnesium, and potassium, which may improve fertility in acidic or degraded soils (Beerling et al., 2020; Skov et al., 2024). Trials in tropical and temperate regions show better soil structure, stronger roots, and 6-21% higher yields, alongside reduced fertiliser needs due to slower nutrient release and lower nitrogen leaching (Vienne et al., 2022; Skov et al., 2024). Effects are context-dependent (rock type and dose, soil and crop, climate), and benefits may take time to materialise. In this light, ERW can function as a relatively low-cost amendment that can improve drought tolerance and support productivity, particularly in acidic, highly weathered tropical soils.

Finally, DACCS, despite higher capital intensity, can act as a flexible, price-responsive load, operating during periods of surplus wind or solar to reduce curtailment and support reliability. Recent optimisation studies demonstrate wind-curtailment-powered and process-flexible DACCS operation, strengthening the case for grid-integration value beyond CDR alone (Liu et al., 2025; Arwa et al., 2025). Additionally, DACCS can create a base demand that triggers the build-out of additional renewable energy and therefore increase energy access in local communities (Qiu et al., 2022).

CDR Diversity: A Strength for the Global South

The developmental value of CDR ultimately depends on how it is deployed. The literature on appropriate technology emphasises that sustainable diffusion, the spreading of a technology suited to its context, occurs when new industries align with local infrastructures, skills, and resource bases (Fu and Shi, 2022; Lema, Fu and Rabellotti, 2020). In the Global South, this principle points toward a diversified mix of CDR pathways. Each operates at a different scale, and infrastructure intensity, allowing countries to match technologies to their comparative advantages. BCR and BECCS can anchor labour-intensive, decentralised industries that build on agricultural and biomass residues, while ERW can strengthen existing mining and transport networks (Woolf et al., 2016; Sanei et al., 2024; Whitehead, 2025).

As Lebdioui (2024) argues, green industrialisation cannot follow a single script. Attempting to replicate Global North technological trajectories risks a fallacy of composition, where countries compete over the same niche rather than building on comparative advantage. CDR, by contrast, opens a portfolio of differentiated industrial pathways. Biomass-rich economies such as Brazil or Indonesia can prioritise BECCS and BCR; mineral-endowed regions like India, Brazil or Kenya can advance EW; and countries with current or future cheap, abundant renewables, Kenya, Chile, Morocco, Brazil, Namibia, can position themselves for DACCS.

This diversity can be an asset: it allows latecomer economies to capture complementary segments of the emerging CDR value chain. By tailoring deployment to context, CDR could become a driver of appropriate industrialisation, creating rural jobs, fostering technological learning, and linking climate mitigation with development.

4. Country Case Studies: Lessons Learned from Bolivia, Brazil, and Kenya

To explore how durable CDR can act as an engine of industrialisation, three country case studies were developed from interviews and operational data collected between August and October 2025. They highlight contrasting configurations of ownership and capital. In Bolivia, **Exomad Green** is a Bolivian-owned and financed company, part of Exomad Group, Bolivia's largest forest products exporter, which has expanded into CDR by converting local woody residues into verified BCR. In Brazil, **NetZero** operates BCR facilities with European capital but a nearly fully domestic workforce. In Kenya, **Octavia Carbon** combines international technology with a locally led team to deploy DACCS amidst a rapidly evolving policy framework, as confirmed in discussions with the **Office of the Special Envoy for Climate Change**. Together, these case studies trace how different constellations of capital, labour, and governance are shaping the first generation of CDR industries in the Global South.

Bolivia - Exomad Green

Bolivia illustrates how a viable carbon-removal industry can emerge before policy frameworks mature. Agriculture represents about 13% of GDP and 27% of employment, while forestry operations generate more than 3.8 Mt of residues each year (ITA, 2024a; CEIC, 2024, Morato et al., 2019). The country only recently created a regulatory foundation for carbon monetisation: Constitutional Ruling 040/2024 and Supreme Decree 5264 explicitly authorised carbon-credit sales and established rules for climate-finance access (Sánchez, 2025; Climate Laws, 2024).

Exomad Green converts sustainably sourced sawmill residues, previously burned or discarded in rivers, into biochar aligned with sustainability criteria for biomass-based CDR. Exomad Green has delivered over 202,000 tonnes of verified carbon removals (with current capacities of 120 ktCO_2/year), making it the world's largest supplier of durable CDR to date (CDR.fyi, 2025b). In May 2025, the company signed a 10-year offtake with Microsoft for at least 1.24 million tCO_2, among the largest CDR transactions worldwide. The deal is likely worth $120-180 million (with a $100-150/t BCR price) (S&P, 2025b). More than 12,000 hectares have been treated with biochar, raising yields by roughly 25% on amended soils. Exomad Green employs ≈ 200 people directly and ≈ 200 indirectly, supporting ≈ 500 families through education, health, and community programmes (this represents 3,000-4000 jobs/Mt, in line with our estimates). Health monitoring around sawmills shows an 83% reduction in conjunctivitis and 89% in respiratory infections after residue burning ceased (Exomad Green, 2025).

Exomad's constraints are financial, not technical: Bolivia lacks domestic investment vehicles, and scale therefore depends on sustained access to international buyers and certification systems. Exomad Green's trajectory demonstrates that when global standards and market access align, resource-rich countries can transform waste streams into rural employment, health benefits, and durable industrial value. Delivering its 1.24 $MtCO_2$ contract would help Exomad Green sustain roughly 800-1000 total jobs[8] over the decade, based on its current labour intensity of about 3,000-4000 jobs/Mt, consolidating Exomad's position as a global leader in CDR.

Brazil - NetZero

Brazil arguably has one of the strongest foundations for large-scale CDR. The country produces 600-770 Mt of agricultural residues annually (Alves et al., 2023), providing abundant feedstock for BCR and BECCS. It also holds around 17% of global above-ground biomass (Fendrich et al., 2025; Flores et al., 2024)[9] and possesses a power mix that is already ~89% renewable, creating favourable conditions for both biomass- and energy-intensive removals. For ERW, Brazil already has enabling frameworks, the Rochagem regulation and the National Fertiliser Plan, yet deployment remains sub-optimal (MAPA, 2017; MAPA/PNF, 2022). Registered production of remineralisers was ~3 Mt in 2021-2022, with ~3 Mha under use in 2022 and a five-year cumulative 7.34 Mha (Embrapa, 2024; Embrapa, 2022). Meanwhile, Brazil imports ~85% of its fertiliser needs and imported ~42 Mt in 2023, a dependency ERW could help reduce by substituting imported inputs with local basaltic resources (ANBA, 2025). Beyond ERW, favourable onshore CO_2 storage formations in the Paraná Basin, including the Rio Bonito saline aquifer with ~12-117 Gt CO_2 estimated capacity, together with a renewable-rich grid (88.2% in 2024) support DACCS viability (Lap et al, 2023; EPE, 2025). Early pilots, ~300 $tCO_2\ yr^{-1}$ in Porto Alegre and up to ~5 $ktCO_2\ yr^{-1}$ in Salvador, demonstrate feasibility and a pathway toward hub formation as regulatory frameworks mature (PUCRS, 2024; SENAI, 2023).

Among the companies emerging within this ecosystem is NetZero, based in Minas Gerais, exemplifying how domestic industrial capability can form around CDR. The firm designs and manufactures its own BCR systems, MRV tools, and agronomic R&D programmes. A single mid-scale plant producing 3,000-4,000 tonnes of biochar per year, equivalent to 8,000-11,000 tCO_2 of verified removals, supports about 25 direct and 25 indirect jobs, or 4,500-6,000 jobs per $MtCO_2$, typically at 1.5 times local wage levels. NetZero aims to remove 5 million tonnes of CO_2 by 2030 through large-scale deployment of its modular systems, which could sustain 5,000-30,000 jobs depending on labour intensity. About 90% of its workforce is Brazilian, half in R&D or

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[8] Assuming capacities increase to deliver the Microsoft deal. 400 existing jobs with added 400-500 new jobs from the Microsoft deal of 0.124 Mt/y for ten years.

[9] Recent work estimates the Amazon stores ~102 ± 26 PgC, about 28% of global AGC. With ~60% of the Amazon in Brazil, that implies ~17% from Brazil's Amazon alone. Adding Brazil's non-Amazon biomes (Cerrado, Atlantic Forest, Pantanal, mangroves), which have lower carbon densities, pushes the national total modestly above 17% (Fendrich et al., 2025; Flores et al., 2024).

engineering, with many employees transitioning from informal trades such as mechanics or farm work into skilled industrial roles. On partner farms, they report yield increases of 15-50% n, sometimes doubling in low-fertiliser systems, while integrated heat recovery reduces both fuel use and particulate pollution. In 2025, NetZero won $15 million as first runner-up in the highly-competitive, international $100 million XPRIZE CDR competition, the only BCR firm among the winners (XPRIZE, 2025), signaling technical credibility and global competitiveness. Its ownership model, European equity paired with a fully national workforce, illustrates how foreign capital can anchor local capability when governance is clear and predictable.

Brazil's regulatory framework has yet to match its potential. The pending SBCE (Sistema Brasileiro de Comércio de Emissões), Brazil's forthcoming national carbon-market law, establishes the framework for a regulated emissions trading system but key design elements remain undefined. In particular, the legislation provides no clear provisions for durable carbon removal, and overlaps oversight with slow permitting deters investors. Despite a push for "green reindustrialisation," Brazil lacks core enablers, taxonomy, procurement, and targeted finance. NetZero's experience shows that policy uncertainty, not funding scarcity, is the main constraint. Clear inclusion of removals in SBCE rules, streamlined permitting, and R&D incentives could support an industrial cluster akin to the ethanol boom of the 1980s. In parallel, Article 6.2 transactions could provide a complementary revenue stream by enabling the export of verified removals toward other countries' NDCs. Broader international recognition of certified Global South removals, particularly under the EU CRCF, would further channel investment to where costs are lowest and co-benefits greatest, turning Brazil's natural endowments into a strategic export sector for high-integrity carbon removals.

Kenya - Octavia Carbon

Kenya appears well-placed for CDR readiness. Over **93%** of its electricity already comes from renewables, mainly geothermal, and the Rift Valley geology provides significant storage potential for captured CO_2 (ITA, 2024b, IEA, 2024d). Agriculture contributes ≈ 22% of GDP and ≈ 33% of employment, with over 70% of rural households engaged in farming (KNBS, 2025, World Bank, 2025b; MIGA/World Bank, 2025). These conditions make the country favourable for both using agricultural residues, and DACCS, powered by low-carbon energy and supported by nearby storage basins, yet removals remain absent from its NDC and unrecognised as a distinct sector.

Founded in 2021 in Nairobi, **Octavia Carbon** has become Africa's most advanced DACCS developer. In three years it has created more than 60 permanent and 100 temporary jobs; 98% of its staff are Kenyan, and over half hold technical roles such as engineering, research or assembly. Partnerships with technical vocational education and training (TVET) institutes have yielded apprentices who are now trainers. The company plans to expand from ≈ 100 tCO_2 per year to 1,000 tCO_2 by 2027, supporting hundreds of jobs and a new domestic supply chain in engineering and manufacturing. Community initiatives, sanitary-pad banks, sports programmes, school partnerships, have built social acceptance and countered fears that Kenya could become a testing ground for foreign technologies.

The policy framework is nascent but advancing. The Climate Change (Amendment) Act 2023 and Carbon Markets Regulations 2024 created a national registry and benefit-sharing rules allocating up to 40% of revenues from land-based projects to local communities. Oversight rests with the National Environment Management Authority. According to Faith Temba, from the Office of the Special Envoy for Climate Change, CDR is integrated into Kenya's broader carbon-market framework, led by the Ministry of Environment and overseen by NEMA, though not yet reflected in the NDC. She described a sequencing approach where policy follows activity and outlined three priorities to explore: a national CDR strategy, NDC inclusion, and an Article 6 whitelist to enable bilateral trade. She emphasised the need for stronger industry engagement and noted that early recognition by EU and US frameworks would help catalyse investment and validate domestic efforts.

Kenya's case shows that where technical capability and resources exist, awareness and coordination are the binding constraints. Policy direction and external validation will determine whether its current "permission to innovate" phase evolves into a full-fledged industrial strategy. If achieved, Kenya could become the first African state to link durable CDR with domestic manufacturing and energy-intensive innovation.

Employment Intensity and Co-Benefits

Early CDR deployment in the Global South is markedly labour-intensive and locally anchored. Current estimates range from ≈3,000 to 15,000 jobs per $MtCO_2$ capacity for BCR projects such as Exomad Green and NetZero, to considerably higher ratios for emerging DACCS initiatives like Octavia Carbon[10]. While these figures will decline as operations scale, they confirm that our Global South employment projections, 2-9 million jobs in 2050, are conservative, particularly for rural, feedstock-based technologies.

[10] Current estimates for Octavia indicate hundreds of thousands of jobs per $MtCO_2$, reflecting its early-stage nature rather than a mature DAC industry. As the sector scales, labour intensity will decline, DAC is not inherently labour-intensive and will likely create fewer jobs per tonne than BCR, yet Octavia's rapid growth currently inflates its job ratios. If the company achieves its goal of scaling to hundreds of thousands of tonnes removed by the early 2030s with a few hundred employees, this would translate to only a few thousand jobs per $MtCO_2$ (for instance, 300-900 of jobs for 100-500 of kilotonnes would correspond to roughly 1,000-9,000 jobs per $MtCO_2$), consistent with expectations for a maturing DAC industry.

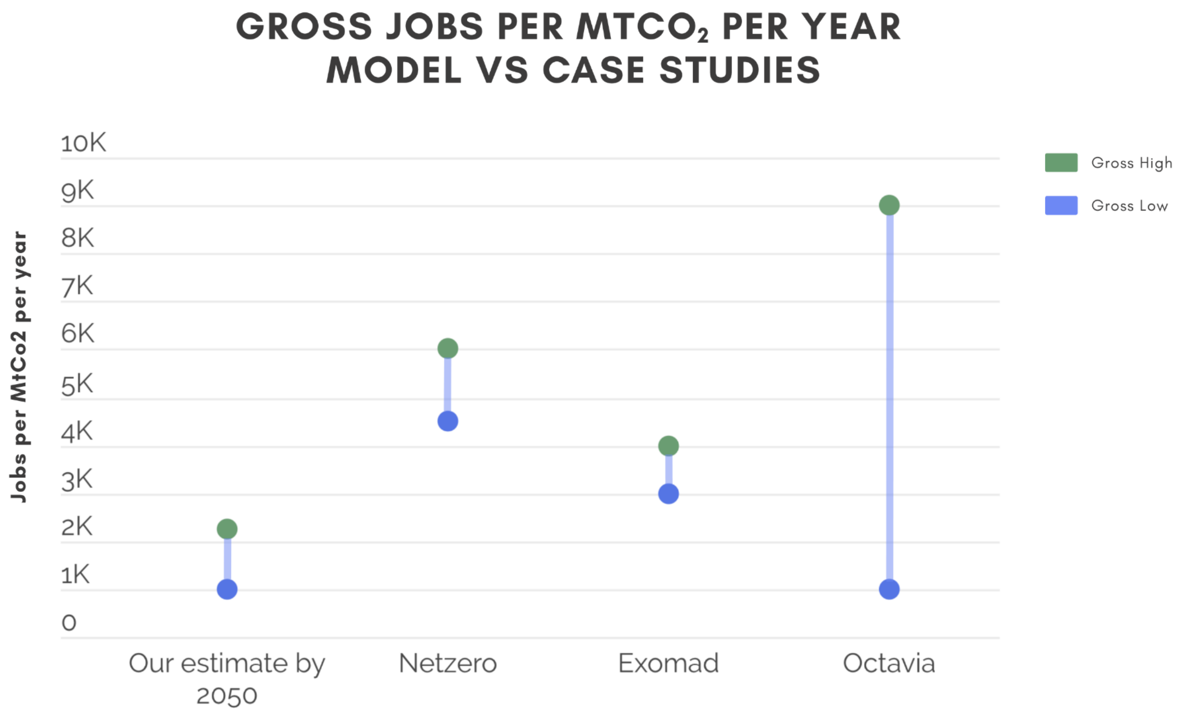

Figure 12: Job per $MtCO_2$ (Case studies)

The cases also validate our broader co-benefits analysis: CDR projects generate tangible local gains, income diversification, skill formation, health improvements, and community investment, well before they reach industrial scale. Taken together, they illustrate how durable CDR can evolve into a development engine, linking climate mitigation with inclusive growth and rural industrialisation across the Global South.

5. Risks of Renewed Extractivism

The expansion of CDR technologies in the Global South presents a significant opportunity for climate leadership, but also the risk of renewed extractivism if social, political, and technological safeguards are weak. While durable CDR can generate industrial development and green infrastructure, poorly governed deployment could reproduce historical imbalances in land use, value capture, and technological dependency.

Large-scale biomass demand for CDR risks tightening land markets and crowding out food production if it extends beyond true residues. Multi-model assessments show that bioenergy-heavy mitigation without safeguards could raise global food prices and place 50-170 million people at risk of hunger by 2050, with the harshest effects in sub-Saharan Africa and South Asia (Hasegawa et al., 2018; IPCC, 2022). Irrigated bioenergy expansion could also double the land and population exposed to severe water stress (Stenzel et al., 2021; Bonsch et al., 2016). These pressures are compounded by insecure land tenure, cited by the IPCC (2019) as a barrier to equitable mitigation. Sustainability assessments estimate that while land-based CDR could, in theory, occupy 4-6 Gha, biodiversity, food, and water limits reduce feasible deployment to 0.5-1 Gha, capping BECCS at 1-2 Gt CO_2 yr^{-1} and demanding 2,000-4,000 km^3 yr^{-1} of freshwater (Deprez et al., 2024). In this context, strong domestic laws are crucial to prevent unsustainable biomass use. Bolivia's Forestry Law No. 1700 (1996), requires approved forest management plans, limits harvesting to authorised production zones, and recognises community and Indigenous user rights. Consequently, CDR frameworks are embedding biomass safeguards, such as under the EU CRCF, where feedstocks must meet RED III criteria (European Commission, 2025a), yet without strong governance, risks of "green grabbing" (Fairhead, et al., 2012) and unequal value capture persist (Günther et al., 2022; Nawaz et al., 2025).

Beyond land and biomass, a newer form of extractivism may emerge through control over intellectual property and governance systems. Recent analysis by the Rhodium Group (2025b) finds that patents on key DACCS technologies, sorbents, contactors, and calciners, are concentrated among a handful of firms, raising barriers to diffusion and reinforcing technological dependency. Similar governance asymmetries arise where measurement, verification, and certification infrastructures remain Northern-controlled, funnelling value to foreign auditors and excluding Southern producers from regulated markets (Sovacool et al., 2023).

Finally, technological misfit can itself become a vector of extractivism. Advanced CDR systems deployed in regions without sufficient energy or infrastructure, such as DACCS in areas with weak or carbon-intensive grids, may depend on imported technology and external finance while consuming scarce low-carbon power. This risks deepening dependency and creating stranded assets, as DACCS requires hundreds of kilowatt-hours of electricity and several gigajoules of heat per tonne of CO_2 captured (Qiu, 2022).

6. Policy Implication

For the Global South, CDR should be conceived not only as a climate tool but as an industrial sector in its own right, capable of generating employment, technology diffusion, and export opportunities alongside climate mitigation benefits. The challenge is to design policies that embed CDR within national development strategies. What distinguishes successful early movers is the ability to coordinate fiscal, technological, and institutional measures around a coherent long-term mission, consistent with recent approaches to mission-oriented industrial policy (UNIDO, 2023; Mazzucato et al., 2024).

The first step is an **analysis of domestic CDR potential**. Countries need a precise understanding of their resource base and comparative advantages: biomass residues that can support BCR or BECCS, renewable energy for DACCS, geological formations suitable for storage, and the suitability of agricultural soils to BCR or ERW. A structured mapping of biological, mineral, and energy endowments can guide infrastructure planning and reduce the risk of technological misalignment. This diagnostic exercise should quantify feasible annual removal potential, identify priority industrial corridors, and link resource availability to logistics, energy systems, and skills.

A second priority is **regulatory clarity and certification integrity**. The EU's Carbon Removal and Carbon Farming Regulation (CRCF) is emerging as the benchmark for defining what constitutes certified high-quality, durable removal. Its influence is likely to extend well beyond European markets, similarly to how the EU's GDPR became the global reference for data protection (Ryngaert, 2020). Aligning domestic certification systems with CRCF's principles, permanence, additionality, and liability, would maximise future market access while providing credibility for domestic actors. Developing countries should embed such policy within a broader national CDR strategy which defines institutional responsibilities, separate CDR targets, and provides guidance for a customized scale up of local industry.

The third priority concerns the **fiscal and financial architecture** required to mobilise early CDR investment. Such projects are capital-intensive and exposed to policy and price risk, making targeted public support essential. Investment tax credits, accelerated depreciation, and CAPEX grants can lower financing costs by 20-30% and attract private participation (USDA, 2023). Examples such as the U.S. 45Q and Canada's CCUS ITC demonstrate the impact of tax incentives, while Denmark's NECCS Fund and Sweden's BECCS contracts show how state-backed schemes can lead to bankability for large projects. The UK's CCfDs further illustrate how long-term offtake contracts provide revenue stability and integrate voluntary demand. For the Global South, credit lines via national development banks and blended-finance mechanisms with concessional or first-loss elements will be key to crowding in private capital and embedding CDR within national industrial strategies.

Fourth, i**nternational market integration** offers a structural source of demand. Article 6.2 of the Paris Agreement provides an already operational framework for the transfer of verified removals as international mitigation outcomes (ITMOs). Bilateral agreements under Article 6.2 could monetise certified CDR at scale and anchor long-term foreign revenue flows. We are seeing clear opening up towards international credits in the Global North, an opportunity the Global South should capitalise on through Article 6.2. For the first time, the European Commission's proposal for the 2040 climate target explicitly foresees the limited use of high-quality international credits under Article 6 (beginning in 2036 and capped at 3 % of EU emissions; European Commission, 2025e). Creating clear national "whitelists" of eligible methodologies and pre-approved technologies would help governments maintain integrity while facilitating trade.

Fifth, **governance and permitting** reform remain essential. Overlapping administrative responsibilities, lengthy approval timelines, and inconsistent environmental classifications often delay project deployment. Dedicated inter-ministerial "green industry desks", harmonised permitting procedures, and exemptions for essential imports could substantially reduce transaction costs. Localisation policies that cluster CDR activities around agro-industrial zones or renewable-energy corridors can generate employment and enable small and medium-sized enterprises to participate in value creation.

Finally, **building skills and research ecosystems** is equally important. The industrialisation of CDR depends on a technically trained workforce, laboratory capacity, and sustained public-private collaboration. Governments and universities should co-finance MRV laboratories and testing facilities, while incorporating CDR into engineering and agricultural curricula. Partnerships with Global North institutions can support methodology development and joint research programmes, ensuring both credibility and local capacity building.

If structured around these principles -diagnostic precision, regulatory integrity, financial mobilisation, international cooperation, streamlined permitting, and domestic skills training - CDR can evolve into a cornerstone of green industrialisation, contributing simultaneously to durable climate mitigation and broad-based economic development.

7. Conclusion: An Overlooked Industrialisation Opportunity

CDR can be the next engine of industrialisation for the Global South. Deploying 3-5 $GtCO_2$ per year by 2050 could sustain 3-9.5 million permanent jobs and generate €300-550 billion in annual value added. Capturing this potential requires coordinated action: the Global South must turn its residues, minerals, and renewables into productive assets through clear roadmaps, investment incentives, and skills ecosystems, while the Global North must open its markets and certification systems to verified Global South removals. Recognising these removals under EU and US frameworks, and co-financing MRV and capacity-building, would lower global abatement costs and support shared prosperity. CDR can either reproduce asymmetry or rebalance it, transforming climate policy into a genuine development strategy. The next green revolution will belong to those who link carbon removal with industrial opportunity, on equal terms across Global North and South.

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