



Full length article

Can South Africa's Carbon Policies Enable Carbon Dioxide Removal Scaling?

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Article Info

Received: 06.10.2025

Accepted: 26.11.2025

Available online: 30.11.2025

Keywords:

Carbon dioxide removal (CDR),
carbon policies, carbon tax,
decarbonisation, South Africa

ABSTRACT

Carbon dioxide removal (CDR) technologies are critical for limiting global warming to below 2°C, ideally 1.5°C. Carbon pricing policies, grounded in Pigouvian tax theory, have played a central role in global decarbonisation efforts. With the growing recognition of CDR's importance in tackling global warming, this study qualitatively assesses South Africa's current and proposed carbon pricing policies through content analysis to evaluate their effectiveness in promoting large-scale investment in CDR technologies. Drawing on policy diffusion and global policy lessons, the study assesses how effectively South Africa's policies incentivize CDR adoption and scale-up. The analysis reveals that current carbon pricing frameworks primarily focus on emissions reductions without explicitly incentivizing the positive externalities of CDR. Key barriers include a lack of CDR specific incentives and limited integration of CDR within the policy design, which impedes alignment with deep decarbonisation goals. The findings suggest that South Africa's carbon pricing policies largely adhere to the polluter pays principle but fall short of addressing the broader climate mitigation potential of CDR technologies. The study concludes that to effectively promote large-scale CDR investment, carbon pricing policies must evolve to integrate targeted incentives designed through policy diffusion by drawing on the experiences and innovations of other jurisdictions. This research contributes to tax policy literature by advocating a more inclusive carbon pricing approach that embraces CDR as a central element of South Africa's emission reduction strategy.

DOI:

<https://doi.org/10.59857/5wnrhy95>

1. Introduction

The 2015 Paris Agreement, a landmark global framework for climate change mitigation, aims to limit global warming to well below 2°C, with an ideal target of 1.5°C above pre-industrial levels (Gao et al., 2017). Despite the significance of this landmark agreement, global efforts to reduce emissions remain inadequate to achieve the established climate targets (Barrett et al., 2024). As the carbon budget for achieving 1.5°C diminishes, the integration of carbon dioxide removal (CDR) with decarbonisation becomes vital (Barrett et al., 2024; Fajardy et al., 2019). Estimates suggest that achieving this target will require the removal of 100 to 1000 gigatons of CO₂ by 2100 (Ampah et al., 2024). Without substantial shift from fossil fuels, global emissions could rise to 80 gigatonnes

of CO₂ annually by the end of the century, driving an estimated temperature increase of 3.5°C above pre-industrial levels (Fuhrman et al., 2023). Temperature increases beyond 2°C intensify and prolongs hot and dry conditions (Hoegh-Guldberg et al., 2019).

The African continent is especially vulnerable to the adverse effects of climate change, including heightened risks to public health, economic development, water availability, and food security (UNFCCC, 2020). South Africa faces substantial challenges, as its annual mean temperatures have increased at a rate at least 1.5 times greater than the global average rise of 0.65°C observed between 2004 and 2014 (Ziervogel et al., 2014). Integrated assessment models indicate that halting the atmospheric accumulation of CO₂ by the latter half of the century is essential to achieving the 1.5°C target and mitigating climate-related risks (Okonkwo et al., 2023). Projections show that, in the absence of new climate policies, South Africa's emissions could increase to 758 metric tons CO₂ by 2050, a 25% rise from current levels (Afrane et al., 2024). To align with the 1.5°C and 2°C pathways, the country must reduce residual emissions by 70% and 45%, respectively, compared to 2020 levels (Afrane et al., 2024). Achieving its domestic net-zero target by 2050 will require even more ambitious reductions of up to 85% (Afrane et al., 2024). These scenarios underscore the insufficiency of emission reduction alone and point to the necessity of scalable CDR technologies to address residual emissions (Afrane et al., 2024; Edelenbosch et al., 2024; Hickey et al., 2023). CDR offers South Africa a pathway to fulfil its climate commitments without resorting to disruptive decarbonisation efforts (Afrane et al., 2024).

Carbon pricing has emerged as a cornerstone of global climate mitigation frameworks (Steinebach et al., 2021). However, empirical evidence suggests that prevailing carbon tax levels have been insufficient to induce the transformative behavioural and structural changes required to shift toward low-carbon development pathways (Baranzini et al., 2017; Boyce, 2018; Makamela & Ramfol, 2023; Rosenbloom et al., 2020). In the South African context, these pricing levels have similarly fallen short in advancing the renewable energy transition (Makamela & Ramfol, 2024a; 2024b). While recent studies have explored the role of CDR in South Africa's decarbonisation strategy (Afrane et al., 2024; 2025), the interaction between carbon pricing mechanisms and large-scale CDR adoption remains largely unexamined.

Given these challenges, this study investigates whether South Africa's carbon pricing policies can support the large-scale deployment of CDR technologies, guided by the central research question: can national carbon policies effectively incentivize CDR adoption at scale? Through qualitative content analysis, the study reviews the role of CDRs in climate goals, analyses South Africa's carbon pricing policies and barriers, and provides recommendations to strengthen CDR incentives for achieving climate objectives.

2. Literature review

2.1 The role of CDR in climate targets

CDR has become a fundamental element of climate policy, playing an essential role in national net-zero strategies and efforts to limit warming to well below 2°C, with a continued focus on achieving the 1.5°C target (Afrane et al., 2025; Brad, Haas, & Schneider, 2024; Buck et al., 2023; Fuhrman et al., 2023; Hickey et al., 2023; IPCC 2022; Okonkwo et al., 2023). CDR is the permanent extraction of carbon dioxide from the atmosphere, capturing of CO₂ that has been previously emitted (Terlouw et al., 2021; McLaren & Corry 2025). CDR encompasses several approaches, including bioenergy with carbon capture and storage (BECCS), direct air capture and storage (DACs), afforestation, ocean fertilization, enhanced mineral weathering, and biochar (Asibor

et al., 2022). DACS filters CO₂ directly from ambient air and stores it underground (Terlouw et al., 2021). Natural solutions like afforestation enhance carbon sinks through forest expansion (Doelman et al., 2020), while ocean fertilisation stimulates phytoplankton growth to increase carbon sequestration in the deep ocean (Jiang et al., 2024). Emerging techniques include enhanced mineral weathering, where silicate minerals are distributed to chemically bind atmospheric CO₂ (Power et al., 2023), and biochar, which converts biomass into a stable carbon-rich form through pyrolysis (Asibor et al., 2022; Anand et al., 2022). These technologies provide the technical basis for long-term carbon removal and climate stabilization.

2.2 Benefits and barriers to CDR deployment

CDR offers a range of other significant benefits in addition to climate benefits. Land-based strategies such as afforestation improve sustainable forest management, agroforestry, soil carbon management, and agricultural practices reducing methane (CH₄) and nitrous oxide (N₂O) emissions (IPCC, 2022; Liu et al., 2022). Soil carbon sequestration, enhanced weathering and biochar contribute to improving soil health and boosting agricultural yields (Dooley, 2020; Tan & Aviso, 2021). Biochar and BECCS technologies offer additional energy generation advantages. Biochar generates energy through pyrolysis while aiding pollution remediation and waste management (Asibor et al., 2022). BECCS provides reliable low-carbon electricity, avoiding the intermittency of renewable sources like wind and solar (Bui et al., 2018). The additional energy benefit has the potential to reduce South Africa's dependence on fossil fuels, thereby achieving a dual advantage of environmental conservation and energy production.

Mitigation strategies face significant challenges in implementation (IPCC, 2022). Many countries have yet to integrate CDR into long-term climate plans, largely due to uncertainties surrounding its technical viability, economic feasibility, and scalability (Asibor et al., 2022). The implementation of CDR on a gigaton scale remains contentious, as the scarcity of demonstration projects, and incomplete assessments of environmental and lifecycle impacts raise doubts about its alignment with climate targets (Terlouw et al., 2021). Scaling CDR presents several challenges, including uncertainties in CO₂ storage capacity and potential ecological and societal risks linked to afforestation and the growth of bioenergy crops (Liu et al., 2023; Edelenbosch et al., 2024). Nevertheless, integrated assessment modelling studies identify BECCS and afforestation as promising approaches for achieving negative emissions, despite their implementation challenges (Realmonte et al., 2019). Afrane et al. (2024) finds that in South Africa, BECCS emerges as the most practical CDR solution, with retrofitting fossil fuel infrastructure for carbon capture and biomass conversion offering a cost-efficient approach to address mitigation challenges specific to the country.

2.3 Carbon policy mechanisms

Large-scale CDR adoption requires robust policies, incentives, and commercialization targets, yet most of the current mechanisms lack sufficient funding and financial support to advance a diverse range of strategies for achieving net-zero emissions (Hickey et al., 2023). These mechanisms predominantly rely on market-based and fiscal approaches, such as carbon markets and subsidies (Hickey et al., 2023). Policy instruments involving regulatory or financial adjustments have been used to influence market and behavioural patterns (Honegger, et al., 2021). Carbon pricing instruments¹ have been pivotal tools in the global effort to combat climate change

¹ Carbon pricing instruments includes both carbon taxes and emissions trading schemes. Both mechanisms put a price on pollution.

(Khan & Johansson, 2022). Carbon pricing instruments function as quintessential Pigouvian taxes by internalising the costs of carbon emissions and encouraging emission reductions (Digitemie & Ekemezie, 2024; Pigou, 1920). Carbon pricing instruments penalise polluters by incorporating the societal costs of pollution into market prices, which raises the cost of goods and services (Kotlán et al., 2021; Cheng et al., 2021; Dissanayake et al., 2020; Li & Deng, 2022; Pigou, 1920). These price increase discourages excessive consumption and drives organizations to adopt more sustainable practices (Dissanayake et al., 2020; Jaqua & Schafa, 2021; Tan et al., 2022). Carbon pricing has been extensively adopted as a central mechanism for climate change mitigation in various countries (Khan & Johansson, 2022) and is a key component of South Africa's climate change mitigation strategy (National Treasury, 2025).

2.4 South Africa's CDR carbon policy framework and policy diffusion

South Africa introduced carbon tax in 2019 as a climate change mitigation strategy (Department of Environment Forestry and Fisheries, 2020). The initial rate was ZAR 120 and has risen to ZAR 236 per tonne of CO₂ in 2025 (National Treasury, 2025). The carbon tax is applied to the total greenhouse gas emissions of a taxpayer for a tax period, measured in carbon dioxide equivalents from fuel combustion, industrial processes, and fugitive emissions (Carbon Tax Act, 2019). South Africa's carbon tax policy integrates CDR incentives through two primary mechanisms: carbon sequestration and carbon offset allowances. Under the Carbon Tax Act of 2019, entities can reduce their tax liability by deducting verified and certified carbon sequestration from their total reported emissions. Carbon sequestration applies to removals achieved through forestry plantations, harvested wood products, and carbon capture and storage (CCS) technologies (Carbon Tax Act, 2019; National Treasury, 2024). Carbon sequestration is often implemented in the land use and forestry sectors, involve removing carbon dioxide from the atmosphere and storing it in vegetation, soil, or geological formations, either through natural processes or engineered solutions (Department of Environment, Forestry and Fisheries, 2020). Beyond land use applications, carbon sequestration involves capturing emissions generated by carbon-intensive industrial activities.

CCS technologies capture carbon from industrial processes and store it either in deep geological formations onsite or in specialized offsite facilities (Ko et al., 2021). Pursuant to the Carbon Tax Act, entities engaged in afforestation, BECCS, or CCS as part of their operations are permitted to offset their taxable emissions by the verified total of sequestered carbon emissions. However, this offset is restricted to their actual emissions levels, as tax obligations cannot result in a negative liability (Carbon Tax Act, 2019). This restriction constrains CDR adoption to current emission levels due to a lack of additional incentives.

The Carbon Tax Act further allows entities to reduce their tax obligations by investing in emission mitigation projects outside their direct operations (Carbon Tax Act, 2019; National Treasury, 2021). Only approved projects complying with Clean Development Mechanism (CDM), Verified Carbon Standard (VCS) and Gold Standard Projects, are allowed carbon offset allowances (National Treasury, 2019). The carbon offset allowance currently limits entities to a reduction of 5% for fugitive and process emissions and 10% for combustion emissions (Carbon Tax Act 2019; National Treasury 2021). Effective from 1 January 2026, the carbon offset allowance will increase by 5% points, reaching 10 % for fugitive and process emissions and 15% for emissions related to combustion activities (National Treasury, 2025). Carbon offset thresholds aim to encourage companies to prioritize reducing emissions within their operations, supporting a net reduction in greenhouse gas emissions (National Treasury, 2021). National Treasury (2024) argues that this view conforms to the global consensus that carbon offsetting

carbon offsetting should serve as a supplementary measure to companies' efforts in achieving net-zero strategies. As illustrated in international examples (Table 1), the global norm is to limit carbon offsets to between 4% and 10% of actual annual emissions.

Table 1: International examples of carbon offsets

Country	Offset instrument	Offset allowance	References
China	China Certified Emission Reduction Programmed	Key emitters can use the CCER, which is no more than 5% of their actual emissions to offset their compliance with allowances.	(Zhu et al., 2024)
South Africa	Carbon Tax and Offsets	Carbon offset of 5% for fugitive and process emissions and 10% for combustion emissions.	(Carbon Tax Act, 2019)
Chile	Carbon Tax and Offsets	Carbon offsets up to a maximum of 5% can be used by companies to meet their carbon tax obligations.	(International Carbon Action Partnership, n.d)
USA - California	Cap and trade system	The use of carbon offsets is limited to 4% for the years 2021 to 2025 and will increase to 6% for the years 2026 to 2030.	(Cullenward & Burtraw, 2022)
Singapore	Carbon tax and offsets	Companies can use high quality international carbon credits to offset up to 5% of their taxable emissions.	(Carbon Markets Cooperation Office, 2024)
South Korea	ETS and Offsets	South Korea implements an ETS scheme and allows offsets of up to a maximum of 5% for the years 2021 to 2025.	(Ecoeye, 2023; International Carbon Action Partnership. (n.d.))

Source: Author's compilation

In its 2024 proposal for the second phase of the carbon tax, the National Treasury advocated increasing the offset allowance to 20% for fugitive and process emissions and 25% for combustion emissions, to be implemented either immediately or through a phased approach (National Treasury, 2024). This signal of higher incentives aims to boost participation in the carbon market and drive investment and innovation in low-carbon technologies, despite exceeding current international benchmarks (National Treasury, 2024).

This divergence, however, aligns with the principles of policy diffusion, which asserts that innovations gradually spread through pre-existing networks within a social system (Rogers, 1983). Policy diffusion theory identifies four fundamental mechanisms: coercion, competition, learning, and emulation, through which the policy decisions of one actor can exert influence over those of others (Simmons et al., 2006). Policymakers learn by observing the political processes and outcomes experienced by other governments (Shipan & Volden, 2008). Similarly, Honegger et al. (2021) outlined five key policy tools to advance CDR: funding for research and development, incentives tied to mitigation outcomes, regulatory mandates, carbon pricing, and supplementary policies to enhance effectiveness. By examining international cases examples of carbon removal incentives, South Africa can leverage policy diffusion to refine and enhance its own incentive structure.

2.5 International CDR fiscal incentives

Comparable international examples demonstrate the value of differentiated incentives in carbon pricing regimes. Switzerland's carbon pricing scheme includes a performance-based subsidy of CHF 100 per ton of CO₂ abated or removed, incentivizing entities to exceed mandated targets (Hintermann & Žarković, 2021). The United States Inflation Reduction Act of 2022 reinforces carbon management by strengthening the 45Q tax credit, increasing incentives for carbon capture and BECCS (Carbon Capture Coalition, 2022; United States Congress, 2022). United States' Section 45Q tax credit, which provides up to USD 85 per ton for CO₂ captured from industrial and power sector activities and permanently stored, and up to USD 180 per ton for direct air capture with secure geological storage (Carbon Capture Coalition, 2023). Similarly, Canada's Investment Tax Credit covers up to 60% of costs for eligible DAC and storage technologies, promoting rapid deployment and private investment (Canada Revenue Agency, 2025).

In addition, Germany is increasingly incorporating CDR into its climate-policy framework. While the EU Emissions Trading System (EU-ETS) remains focused on emissions reduction, Germany is developing complementary legal and fiscal instruments to enable CDR. In 2024, the Federal Cabinet adopted core elements of a Carbon Management Strategy and amendments to the Carbon Storage Act to permit carbon capture and storage (CCS) or carbon capture and utilization (CCU) deployment in hard-to-abate industries (Federal Ministry for Economic Affairs and Climate Action, 2024a, 2024b). Budget proposals for 2026 allocate more than €111 million to negative-emissions initiatives, including €98 million for removal projects and €11.5 million for public procurement of removal certificates, alongside funding for soil-carbon enhancement (DVNE, 2025; DVNE & BCG, 2025). Germany's Carbon Contracts for Difference scheme is also being expanded to subsidise CCS/CCU projects within its industrial decarbonisation programme (Dena, 2025; Jones Day, 2025). These developments reflect academic assessments that Germany could sustain a diversified CDR portfolio: spanning DAC, bio-based and land-based approaches, if supported by strong governance structures (Borchers et al., 2024; Förster et al., 2022). Policy diffusion allows nations to draw insights from established frameworks, modify them to suit local contexts, and integrate national strategies within global climate governance structures (IPCC, 2022). This demonstrates that despite surpassing international carbon offsets benchmark, international models illustrate that nations can blend carbon pricing with targeted fiscal instruments to support carbon removals. Through policy diffusion, countries like South Africa can draw lessons from Germany, Switzerland, the U.S., and Canada, adapting such mechanisms to their contexts and stimulating CDR deployment.

3. Methodology

This study applies a theory-driven qualitative content analysis to evaluate whether South Africa's carbon pricing policies support large-scale carbon dioxide removal (CDR). The analysis is guided by Pigouvian tax theory (Pigou, 1920), which assesses the internalisation of environmental externalities, and policy diffusion theory (Berry & Berry, 1990; Shipan & Volden, 2008; Simons et al., 2006), which explains how policy innovations are adopted. Data comprise the Carbon Tax Act (2019), related policy documents, government reports, and academic literature published between 2019 and 2025. Texts were systematically coded using a combination of deductive codes derived from theory and inductive codes emerging from the material. The analysis focuses on two themes: (1) integration of CDR into carbon pricing and deep decarbonisation strategies, and (2) the presence of CDR-related incentives, highlighting policy gaps and opportunities for strengthening support mechanisms.

4. Findings

The analysis indicates that South Africa's carbon pricing framework prioritizes emissions reductions but lacks explicit incentives for CDR, limiting its ability to drive large-scale removal efforts. In contrast, international models actively incorporate financial mechanisms tailored to CDR deployment. Switzerland's performance-based subsidy, the U.S. Section 45Q tax credit, Canada's Investment Tax Credit and Germany's emerging CDR-enabling instruments, demonstrate how differentiated fiscal incentives strengthen carbon pricing frameworks by aligning mitigation efforts with removal incentives. Compared with these international models, South Africa's approach remains significantly less mature. South Africa's restrictive offset caps (5–25%), low carbon tax rate, and continued fossil fuel subsidies further reduce the economic feasibility of transformative carbon removal strategies. These findings underscore the importance of policy diffusion in adapting global practices to enhance South Africa's carbon pricing model and advance long-term decarbonisation objectives.

5. Discussion

South Africa's current and proposed carbon pricing framework imposes a 5% to 20% cap on fugitive and process emissions and a 10% to 25% cap on combustion emissions (National Treasury, 2021; National Treasury, 2024), constraining investment in CDR technologies beyond these regulatory limits. As a result, mitigation strategies remain largely focused on incremental emissions avoidance rather than transformative carbon removal, limiting the country's ability to meet deep decarbonisation targets.

A low carbon tax rate, generous free allowances, and continued fossil fuel subsidies further weaken the price signal required to incentivize large-scale removal efforts, as outlined in Pigouvian tax theory (International Institute for Sustainable Development, 2019; Makamela & Ramfol, 2023; Skovgaard & van Asselt, 2019; Van Heerden et al., 2016). These structural barriers make large-scale CDR economically unviable, hindering alignment with net-zero objectives. Without policy reform, national emissions are projected to increase by 25% to 758 metric tons CO₂ by 2050, highlighting the inadequacy of an avoidance-only approach (Afrane et al., 2024; Hickey et al., 2023).

While South Africa's carbon pricing model aligns structurally with global frameworks, its failure to integrate dedicated CDR incentives hinders the expansion of removal technologies. Insights from international case studies illustrate how targeted financial mechanisms can stimulate CDR investment. Switzerland's performance-based subsidy, the U.S. Section 45Q tax credit, and Canada's Investment Tax Credit provide viable models that South Africa can adapt to strengthen its incentive structures. By applying policy diffusion principles (Simmons et al., 2006), South Africa can implement established fiscal instruments while adjusting them to suit its regulatory and economic context. The incorporation of differentiated subsidies, tax credits, and regulatory policies would shift mitigation strategies from avoidance-focused approaches to scalable carbon removal solutions.

6. Conclusion

Integrated assessment models underscore the necessity of CDR for South Africa to reach net-zero by 2050 and align with the global 1.5°C pathway, as decarbonisation alone cannot fully eliminate residual emissions (Okonkwo et al., 2023; Edelenbosch et al., 2024; Hickey et al., 2023). However, the current carbon tax and offset system, with allowances capped between 5% to 25% and limited sequestration credits, inadequate provides incentives for large-scale removal efforts. Additionally, the low carbon tax rate, extensive free allowances, and ongoing fossil fuel subsidies weaken the price signal required to support meaningful decarbonisation

(International Institute for Sustainable Development, 2019; Makamela & Ramfol, 2023; Skovgaard & van Asselt, 2019; Van Heerden et al., 2016). These structural limitations constrain both emissions reduction and large-scale atmospheric carbon extraction, ultimately impeding the effectiveness of South Africa's climate mitigation strategy.

To address these shortcomings, South Africa must develop a national CDR roadmap with clear targets, funding mechanisms, and institutional mandates to facilitate large-scale removal initiatives. Strengthening monitoring, reporting, and verification processes will be essential to ensuring transparency and permanence in removal projects. Effective implementation requires that carbon pricing strategies incorporate international best practices to enhance fiscal incentives and attract investment. Policy diffusion provides a valuable framework for South Africa to refine its carbon pricing mechanisms by adopting similar fiscal models from Switzerland, the United States, and Canada, which have integrated CDR specific incentives to promote large-scale adoption. Switzerland's performance-based subsidy, the U.S. Section 45Q tax credit, and Canada's Investment Tax Credit (Hintermann & Žarković, 2021; Carbon Capture Coalition, 2023; Canada Revenue Agency, 2025) exemplify financial mechanisms that South Africa can tailor to its economic and regulatory landscape.

Additionally, structured policy tools: including funding for research and development, mitigation-linked incentives, regulatory mandates, carbon pricing, and supplementary measures (Honegger et al., 2021), offer a framework for refining South Africa's incentive model. Integrating these tools within a policy diffusion strategy will facilitate the transition from avoidance-based fiscal policies to actively supporting large-scale carbon removal efforts.

Public-private collaboration, supported by strategic subsidies and investment assurances, is critical to scaling CDR technologies and mitigating financial risks associated with emerging removal methods. By leveraging the learning diffusion (Simons et al., 2006), South Africa can transition its carbon pricing approach from incremental mitigation to a comprehensive driver of large-scale removal. This shift will not only align national policies with global climate objectives but also reinforce South Africa's economic resilience against escalating climate risks.

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