Investing in Carbon Removal: Levers for the Private Sector

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September 2024

Oxford Sustainable Finance Group, Smith School of Enterprise and the Environment, University of Oxford | Working Paper No. 24-1

ISSN 2732-4214 (Online)

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Acknowledgements

The author would like to thank internal reviewers Ben Caldecott, Gireesh Shrimali, and Matilda Becker for their review. Thanks also to Sam Fankhauser, Johanna Arlinghaus, Steve Smith and others from the CO2RE Policy Working Group who provided insightful comments on an earlier version. The views expressed in this paper are those of the author alone, as is responsibility for any errors or omissions.

Suggested citation

Johnstone, I. (2024), “Investing in Carbon Removal: Levers for the Private Sector”, University of Oxford Smith School of Enterprise and the Environment Working Paper 24-1.

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Abstract

Achieving and maintaining the global goal of net zero requires us to scale carbon removal significantly. Both public and private investment is needed for this task. Recent years have borne witness to a rapid growth in private sector investment in carbon removal, particularly novel technologies. While such interest has typically focused on the use of carbon removal for offsetting purposes, there is a far more diverse range of potential levers through which the private sector can both channel and benefit from carbon removal investment. On the supply side, the private sector can acquire carbon removal assets, invest in carbon removal entities, or integrate carbon removal into their own value chains. On the demand side, opportunities persist for the private sector to support carbon removal through market mechanisms and catalytic climate finance. Such opportunities must be considered against the backdrop of evolving dynamics affecting such investments including efforts to standardise quality, harmonise carbon markets, and the development of innovative products and services. This working paper aims to shed light on these investment levers and evolving dynamics: illustrating how private-sector investment can be channelled to grow the carbon removal “net” in net zero.

Executive Summary

Carbon removal is essential to achieve the Paris Agreement's aim of limiting warming to well below 2°C while pursuing efforts to limit warming to 1.5°C. Nevertheless, an evident gap exists between the volume of carbon removal required to neutralise future residual emissions, and the pace at which carbon removal capacity is being developed and deployed today. Multiple barriers contribute to this gap, spanning from a lack of regulatory support to technological uncertainty. Yet, the most notable barrier is inadequate investment. Amid highly constrained public budgets, private-sector investment has emerged as a pivotal force in nurturing the burgeoning carbon removal industry. It could likewise be a decisive factor in scaling carbon removal to the levels needed to limit future temperature rise.

The private sector has already demonstrated considerable support towards achieving the Paris Agreement, with half of the world's largest companies having committed to net zero targets. These commitments, in turn, have fuelled a surge in private capital directed towards carbon credits to offset corporate emissions. However, the majority of carbon credits sold to date pertain to projects that avoid or reduce carbon emissions rather than removing them. Furthermore, removal investments have principally been for conventional rather than novel carbon removal technologies, due to the sizeable cost and limited supply of the latter. Consequently, the need arises to scale the absolute volumes of carbon removal occurring, whilst also ensuring sufficient durability to counterbalance residual emissions and reach global net zero.

The private sector possesses a wide range of levers to invest in carbon removal. This working paper outlines these levers and provides real-world examples of their deployment. By doing so, it unveils the diverse ways in which the private sector can support the development of carbon removal and, therefore, contribute significantly to the pursuit of the Paris Agreement's goals. At the same time, it highlights the need to recognise the opportunities and headwinds from the voluntary carbon market at large that affect the carbon-removal investment landscape, including in the areas of standardisation, market convergence and innovation. By presenting this overview, the working paper demonstrates the rich potential that exists for the private sector to invest in carbon removal as both a public and private good.

1. Introduction

Net zero is achieved when residual emissions are balanced by anthropogenic removals (IPCC, 2022:1809). Anthropogenic removals, in turn, are the withdrawal of greenhouse gas emissions from the atmosphere as a result of deliberate human activities (IPCC, 2022:1795). Anthropogenic removals that extract carbon dioxide from the atmosphere are known as carbon removal. Carbon removal today predominately occurs via land-based projects, such as planting forests or restoring wetlands (So et al., 2024). However, there is a range of nascent but growing novel carbon removal techniques, from biochar to mineralisation (Smith et al., 2024). Despite the variety of avenues for carbon removal, there remains a significant gap between their current rate of deployment and the levels needed to meet the Paris Agreement's temperature goal of limiting warming to well below 2 degrees (Smith et al., 2024).

Fortunately, the private sector has also signalled its commitment to the Paris Agreement and could help reach this aim. The majority of the world's largest companies have now set net-zero targets (Zero Tracker, 2024). Achieving these targets requires reducing one's own organisational emissions before offsetting the residual emissions with increasing thresholds of durable carbon removal (Axelsson et al., 2024). Yet as net-zero targets often remain voluntary: so too does demand for and investment in carbon removal. Indeed carbon removal credits constitute less than 10% of trading on the voluntary carbon market (Fuss et al., 2024). As a result, there is a strong case for growing carbon removal investment via the voluntary carbon market. Yet a narrow focus on offsetting practices obscures a much broader array of investment levers that have emerged in recent years.

This working paper maps the various levers the private sector has at its disposal to invest in carbon removal and considers the broader policy and regulatory landscape affecting such decisions. Section 2 introduces the current state of play of removal investment — establishing current trends as well as future needs and incentives. Section Three introduces the 12 levers for carbon removal investment and considers their contribution to addressing the investment gap. Section Four then contextualises the opportunity that these levers present through a review of emerging market dynamics. Section Five concludes.

2. State of Play: The Carbon Removal Investment Gap

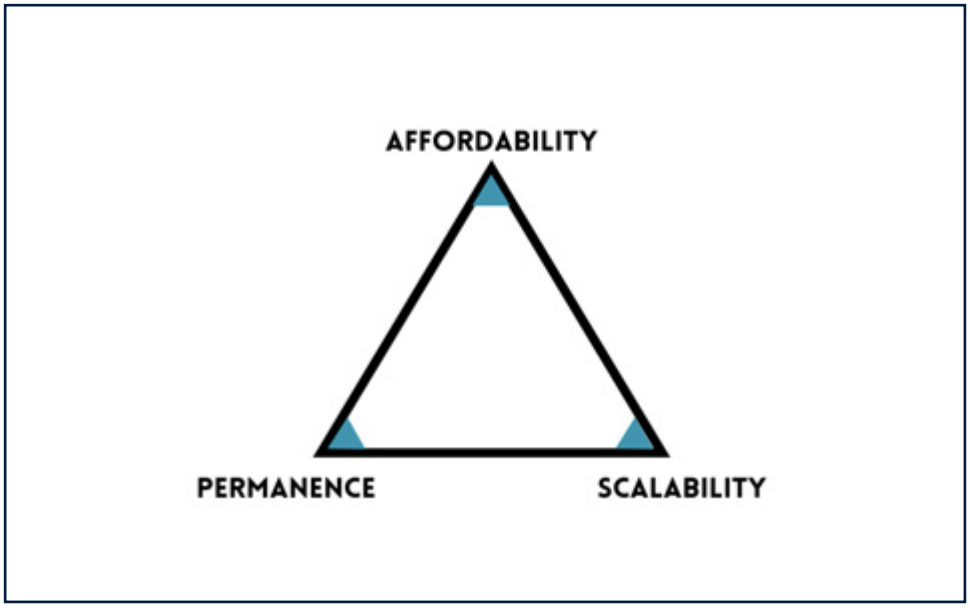
Earth's natural terrestrial and oceanic sinks have absorbed the majority of greenhouse-gas emissions to date, yet its capacity to do so remains limited, leading to an increase in atmospheric concentrations of greenhouse gases in the atmosphere including carbon dioxide. By contrast, carbon removal depends on active human intervention to extract and store carbon. Interventions to draw down and store carbon on meaningful timescales often require more significant capital outlays than emission reduction or avoidance projects: making increased near-term investment an imperative.

2.1 The Need for Carbon Removal and Barriers to its Realisation

As the IPCC acknowledges in its Sixth Assessment Report, carbon removal is indispensable to meet the Paris Agreement's temperature target of limiting temperature increase to 1.5°C and staying well below 2°C (IPCC, 2022:85). According to Paris-aligned modelling scenarios, by 2100 we can expect to have needed to durably remove between 20-660 $GtCO_2$ (Smith et al., 2023:10). The considerable uncertainty surrounding the absolute volume of carbon removal needed over this century stems from persistently high emission levels and the unknown responses of terrestrial and oceanic sinks to future warming (Keller et al., 2018). Even so, it is still estimated that we will need significant sums of novel carbon removal in future, increasing current deployment as much as 30x by 2030 and 1,300x by 2050 (Smith et al., 2023:10). At the same time, considerable investment is needed today also to enhance conventional carbon sinks such as forests and wetlands. As a result, there is a clear need to scale both novel and conventional carbon removal today to make sure it is available in the volumes needed tomorrow.

The term "carbon removal" encompasses a diverse range of carbon sequestration and absorption techniques. Nature-based solutions (NBS), for instance, aim to enhance the natural sequestration abilities of terrestrial or oceanic carbon sinks through practices such as afforestation, reforestation & revegetation (ARR) and blue-carbon solutions. Novel carbon removal also includes an array of techniques, from direct air-carbon capture and storage (DACCS) and mineralisation. Some techniques encompass both conventional and novel components, for instance, biochar, enhanced weathering, bioenergy and carbon capture and storage (BECCS). The range of techniques, in turn, implies varying levels of capex and opex to set up a project. This in turn affects the cost of carbon credits that a carbon removal project generates. Indeed, conventional carbon removal costs — which in 2023 ranged from US $12-$16 per credit — cost on average three times more than credits generated from

emissions reduction or avoidance projects while the average weighted price for novel CDR credits ranges from US $111-$1608 (Fuss et al., 2024). While affordability is important, so too is its permanence, as carbon must be stored over a timescale sufficient to impact the overall climate-warming signal. Indeed, it can be cost-effective and practicable to front-load the cost of longer-duration carbon storage, than to continuously restore temporary carbon sinks (Prado and MacDowell, 2023). Setting the challenges of cost and permanence aside, there are varying other constraints on scaling carbon removal: from resource inputs such as land and electricity to social acceptance. As a result, affordability, permanence and scalability create a trilemma for current and future carbon removal deployment.



Box one: The Carbon Removal Trilemma

The carbon removal trilemma presented in Box One is continuously evolving. Presently, conventional carbon removal tends to excel in scalability and affordability, whereas novel carbon removal exhibits greater permanence. Decision makers, including investors, must navigate this triad to make sustainable investments in carbon removal over time. Despite evident complexity, certain ''no-regrets" carbon removal techniques that are cost-effective and yield co-benefits are evident (Caldecott et al., 2015:5). Yet these alone are not sufficient to reach and sustain net zero. For this reason, additional investment is still required to close the growing carbon removal gap.

2.2 Why Invest in Removals

There are a variety of reasons why an entity may invest in removals. One of the primary reasons that corporates may consider such investment is as part of their offsetting strategy to reach net zero. Yet with only 0.5% of 5,998 companies that have committed to or validated science-based targets having purchased durable carbon removal (SBTi, 2024: 10), considering the wider rationales for investment, beyond offsetting, can yield further insights. Table 1 presents the many dimensions that may influence a private sector actor to invest in carbon removal:

Table 1: *Varying Incentives Underlying Carbon Removal Investment*

Mechanism	Definition	Evidence
Economic Opportunity	Developing carbon removal capacity, as well as indirectly through the provision of net-zero aligned goods and services.	Estimates are that carbon removal could become a $1.2 Trillion USD industry by 2050 (McKinsey & Company, 2023).
Business Advantage	Growing demand for carbon removal, paired with a limited near-term supply, means that the cost of reaching net zero and interim targets in future will only continue to rise. Investors with the foresight to secure forward supply can secure it 3in as cost-efficient manner as possible.	There is a significant lag time between the contracting and delivery of novel carbon removal. Multi-year offtake agreements concluded now include deliveries happening as far in the future as 11 years from now (CDR.FYI, 2024a).
Reputational Reward	Organisations can cultivate a more positive corporate image by setting a net-zero target and taking robust	SBTi found that close to half of all corporate respondents to a recent survey purchased and retired

	investment steps towards meeting it, including via carbon removal.	carbon credits to strengthen their brand (SBTI, 2024:29).
Reducing Reputational & Legal Risk	Investment into carbon removal can also lessen perceived or actual reputational and legal risks attached to offsetting strategies, including risk of non-delivery.	Legal risk can abound when offsetting, for instance, Delta Airlines is facing a $1 Billion USD lawsuit concerning its offsetting strategy (Climate Case Chart, 2024).
Compliance Requirements	Carbon removal units in some jurisdictions can be used to meet compliance requirements under emissions trading schemes or carbon taxes.	New Zealand has integrated forestry-based carbon removals into its Emission Trading Scheme since 2008.
Restoring Nature	Some forms of nature-based carbon removals–including ecosystem-based reforestation & revegetation– offer contributions towards preserving and enhancing nature in line with an emerging array of corporate nature targets.	The Science-based Target Network and Taskforce for Nature-related Financial Disclosures have emerged as a means for organisations to set and measure opportunities and dependencies on relying on nature.
Research & Development	There is potential that R&D into carbon removal could spark innovations that can be used for future commercial advantage.	The Rocky Mountain's Applied Innovation Roadmap for CDR indicates there are 32 separate CDR pathways requiring varying levels of R&D support (Rocky Mountain Institute, 2023).
Social Licence	Investment into carbon removal can provide, if paired with deep and absolute emissions reductions across Scopes 1-3, entities with	Creating and maintaining a social licence is imperative both to develop the carbon removal industry and to illustrate the net-

	significant hard-to-abate emissions a continued social licence for their business model.	zero pathway that hard-to-abate sectors may have available (Psarras et al., 2024).
Climate Contribution	Carbon removal is a vital public good; by investing in it the private sector can make a valuable contribution to climate-change mitigation.	Corporates are increasingly being encouraged to adopt a climate contribution rather than compensation frame (SBTi, 2024).

2.3 Investment Trends to Date

The voluntary carbon market (VCM) remains one of the most familiar channels through which private capital is invested in carbon removal. In 2022 the VCM as a whole reached an annual value of $2 billion USD, facilitated by the trade of 475 million credits, each representing a ton of CO_2 or CO_2e avoided, reduced, or removed (World Bank, 2023a:15,37). A predominant share of this financial inflow to climate-change projects has been associated with offsetting claims. Despite offsetting serving as a primary driver of carbon removal investment, carbon removal commands only a minimal portion within the broader landscape of the voluntary carbon market (Fuss et al., 2024). This dynamic has resulted in the VCM tending to fund projects that avoid or reduce emissions rather than actively removing carbon (Fuss et al., 2024). Conventional carbon removal also tends to be favoured over novel carbon removal in absolute terms, despite growth in demand for the former rather than the latter (Fuss et al., 2024). Moving beyond the VCM, there is also a nascent but noticeable trend of more bespoke investment vehicles, such as offtake agreements and advanced market commitments, being made for novel carbon removal (Fuss et al., 2024).

2.3.1 Investment in projects that avoid rather than remove emissions

The pricing dynamics within the VCM showcase the critical distinction between credits from projects focused on avoiding or reducing emissions and those centred on removal. Carbon credits issued from emissions avoidance or reduction tend to carry a lower price point than those from removal (Fuss et al., 2024). This is because, in general, they tend to require less initial and ongoing capex and opex from a project-development perspective, whilst also generating higher volumes due to the use of counterfactual baseline scenarios. Because of their lower price point (3x less than conventional carbon removal), they tend to be used to offset entities' emissions at scale (Fuss et al., 2024). This feature constrains the flow of financing into carbon removal, with conventional and novel carbon removal projects representing a mere 5% of carbon credit issued and 6% of retirements across the six major carbon credit platforms in 2023.[1] The current status quo of the market demonstrates that carbon removal projects which have a higher price point are being crowded out in favour of projects that may have lower environmental integrity (West et al., 2023). The varying range of project types and credit quality on the VCM has also led to considerable market volatility, with an 80% decline in the prices of some categories of carbon credits in recent years (Twidale and Mcfarlane, 2023). As a result, the vast price differential between avoidance and emission reduction credits on the one hand and conventional and novel carbon removal on the other hand, contributes to a lack of investment scale and certainty for carbon removal project developers. Growing awareness of the need to shift to carbon removal offsetting to reach net zero in line with the Oxford Principles for Net Zero Carbon Alignment could, however, help turn this tide (Axelsson et al., 2024).

2.3.2 Investment in conventional over novel carbon removal

Despite the hurdles involved in attracting investment into carbon removal via the VCM, an estimated 2 billion tonnes of carbon removal occurs each year (Smith et al., 2024:10). However, only part of this–1.3 million—comes from novel carbon removal (Smith et al., 2024:11). The predominance of conventional carbon removal is largely attributed to its lower cost and higher scalability. As novel carbon removal cannot compete with conventional removal in terms of pricing, more sophisticated buyers are increasingly entering the market with strategies to develop a diverse suite of both conventional and novel removals. As of mid-2024, the ecosystem for the latter now boasts approximately 381 suppliers, 369 purchasers, and 169 marketplaces, registries & other supporting infrastructure (CDR FYI,

[1] Based on Johnstone, I. et al. (2024). *Chapter 4- VCM Dataset.* https://zenodo.org/records/11175474.

2024). However, of the 11,028,282 tCO_2e of novel carbon removal that has been sold, only 2.9% has been delivered (CDR FYI, 2024). As a result, not only has there been more investment into conventional removal to date, there is also evidence of bifurcation from a funding perspective, with conventional carbon removal predominantly being funded via the traditional VCM and novel carbon removal being funded by bilateral offtake agreements. The latter has seen significant growth, for instance, sales in Q1 of 2024 were 14.8x what they were year on year in Q1 2023 (CDR.FYI, 2024b) and is further encouraged by Principle 4 of the Oxford Offsetting Principles for Net Zero Carbon Alignment (Axelsson et al., 2024).

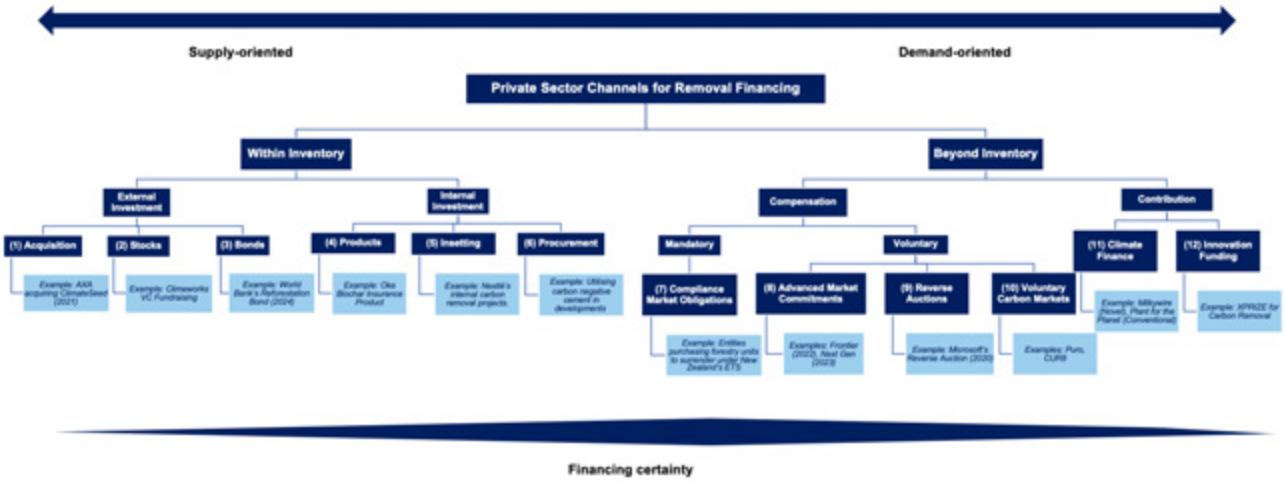
Overall, the two market trends reflect that capital in climate mitigation projects has tended to follow the path of least resistance (and cost). The reliance on the VCM as the primary channel for private investment into carbon removal presents several challenges. While the VCM is projected to grow to USD $1 Trillion by 2050 (Bloomberg NEF, 2023), the predominant preference for emissions avoidance or reduction-based offsets, coupled with a bias towards conventional over novel carbon removal, limits the VCM's effectiveness in scaling durable carbon removal. Moreover, while direct investment via offtake agreements has yielded significant funding for novel carbon removal in recent years, it is not as efficient a market mechanism as the VCM, limiting its ability to scale. On this basis, it becomes necessary to consider an expanded range of options to unleash the full potential of private sector capital to scale carbon removal effectively and efficiently.

3. Options for Private Sector Investment in Carbon Removal

The private sector has a diverse array of potential investment avenues to address the crucial financing needs of carbon removal projects. This section examines these levers, utilising recent examples to highlight the potential of each respective avenue to bridge the carbon removal investment gap.

3.1 Typology

Box Two introduces a Typology of Private Sector Levers for Removal Investment that outlines the channels through which the private sector can strategically invest in carbon removal, complementing Hickey et al.'s (2023) rubric which covers public sector levers for deployment. Each lever is categorised along two primary axes: its focus on either the supply or demand side of the carbon removal equation and the certainty it provides as a form of carbon removal financing. Despite being presented as distinct levers, many can, in fact, be deployed in a complementary manner. Moreover, while initially presented as a private-sector typology, many of these options can also serve as the groundwork for public-private partnerships or as further channels for public financing (US Department of Energy, 2023; US Department of Energy, 2024). While not all levers are created equal–both in terms of the absolute and relative share of investment they could drive into carbon removal– they each can play a role in helping to scale investment into it: underscoring the value of appreciating the wide range of levers the private sector has at its disposal to invest in carbon removal.



Box two: Typology of Private Sector Levers for Removal Investment

Supply-oriented measures relate to levers that principally operate to scale supply, whilst demand-oriented measures provide confidence to project developers. Financing certainty describes the extent to which the lever provides a reliable form of financing from the project developer's perspective.

These levers have a range of different impacts in terms of the scale of prospective investment into carbon removal. They are also likely to see considerable flux in terms of both their relative magnitude and importance for attracting investment. For example, presently the voluntary demand generates much of the investment in novel carbon removal. In future, this demand, and thus investment potential, could come from integrating carbon removal into compliance markets which have a far greater market reach (Fuss et al., 2024). Facing escalating regulations that necessitate the disclosure of climate risk, many private sector actors are beginning to account for their climate impacts across the different scopes of their operations and to develop corporate transition plans (Transition Planning Taskforce, 2024). This could incentivise the deployment of levers within an entity's inventory boundary of scopes 1, 2 and 3 emissions (GHG Protocol, 2019). At the same time, there are options that lie beyond this inventory where a corporate investment into carbon removal could have an impact yet often remain untapped.

3.2 Within Inventory Levers

Organisational climate mitigation strategies begin by accounting for their current levels of greenhouse-gas emissions and taking steps within their value chain to lower them. Within this context, there are several mechanisms to invest in carbon removal both external and internal to a given actor's operations.

3.2.1 External Investment

The private sector can (re)direct its external investment into carbon removal through various avenues including the acquisition of entities, capital injections via venture capital, or investing in corporate bonds or stocks. For the most part, these channels relate to an entity's Scope 3 category of "invested emissions" though careful attributional accounting is needed to ensure there is no double-claiming of value-chain removals (GHG Protocol, 2019):

(1) **Acquisitions:** Various carbon removal projects, services and platforms have emerged in recent years. As these ventures begin to mature, there is now the opportunity for private-sector actors to acquire them as investments. Such acquisitions may or may not be directly relevant to the current value chain of an entity. For instance, in July 2023, Exxon, an oil and gas major, acquired Denbury–a firm that offers expertise in carbon capture, utilisation, and storage (Exxon Mobil, 2023). On the other end of the spectrum, the global investment manager AXA acquired ClimateSeed, a provider of carbon credits in July 2021 (Axa, 2021). In this way, it is clear that acquisitions can drive investment into the carbon removal value chain.

(2) **Stocks:** An alternative to acquisition that is potentially more accessible to a larger number of private-sector actors is investment via stocks. Contributing capital in this manner provides a crucial lifeline to carbon removal developers, who often grapple with significant upfront development costs. Such investment may involve active pathways, such as contributing funding to venture-capital funding rounds in exchange for stock, or more passive investment via the stock exchange. There is a clear appetite from the private sector to deliver capital via these channels, for instance, Climeworks — a developer of Direct Air Carbon Capture — successfully raised over USD $650 Million in its 2022 funding round (Climeworks, 2023). To steward this landscape, several climate-and-removal focused venture capital firms have also emerged in recent years to facilitate such investments– further easing the transaction costs for entities looking to invest (Counteract, 2024).

(3) **Bonds:** Green bonds constitute another avenue for carbon removal investments from the private sector. Indeed, bonds have already been developed in the context of carbon capture and storage, a technology also applicable to some carbon removal techniques (Norton Rose Fulbright, 2022). Such bonds may also be made tax-exempt by some regional and local governments, making them even more attractive investment prospects (Norton Rose Fulbright, 2022). As an early prototype of this potential, 2023 saw a world-first launch of private-sector bonds related to emissions reduction projects (World Bank, 2023b). As of August 2024, this process has now been replicated for carbon removal in the form of an Amazonian afforestation project (World Bank, 2024). Funding carbon removal via a bond model not only ensures that project developers have a more diversified investment stream than can be provided by the comparatively volatile carbon markets but could also offer the private sector a return in the form of carbon credits in lieu of interest payments (Wall Street Journal, 2022). Consequently, investing in green bonds remains another lever through which private sector capital can be deployed to increase carbon removal.

3.2.2 Internal Investment

An organisation has several levers internal to its value chain to direct carbon removal investment. Such levers include developing new product offerings or carbon-insetting projects as well as shifting procurement processes.

(1) **Products:** The private sector has the potential to create products that remove carbon or are tailored to support carbon removal projects. Real-economy actors have the potential to contribute with such products as carbon-negative cement. Financial entities such as banks and insurers can also develop concessional or bespoke financial products for the carbon-removal ecosystem, such as loans or insurance. Product innovation in this sense would not only aid the entity in its journey to reduce its Scope 3 financed or insured emissions but could also reduce the cost of capital for carbon removal project developers, reducing the barriers to scaling and the risk that buyers may face (Sustainable Markets Initiative, 2021). Such financial products have recently been paired with credit offtake agreements to create a further win-win opportunity for both developers and prospective purchasers of carbon removal (BCG, 2023).

(2) **Insetting:** Private sector entities can establish their own carbon removal projects and thus “inset” as a means of directing capital towards net-zero alignment. Since project developers contributing carbon removal-based carbon credits to the VCM are

predominantly from the private sector, it also makes sense that if armed with the right expertise, private sector entities could develop their own in-house carbon removal capabilities. These “insets” can be used to mitigate an entity’s net emissions on-site or sold externally for others’ offsetting purposes. The development of inset projects provides private-sector actors with greater oversight over carbon removal initiatives and the opportunity to leverage their companies’ assets–such as dormant land–in creative ways. Nevertheless, due care must be taken to ensure no double counting occurs if selling units of carbon removal as an offset to others.

(3) **Procurement:** The private sector can also foster carbon removal development through the integration of carbon removal by-products into their supply chains. Indeed, among the carbon removal start-ups participating in the current X-PRIZE for carbon removal, the sale of by-products has emerged as the most significant form of financing for early-stage novel carbon removal ventures (XPRIZE and Musk Foundation, 2023). Abundant opportunities for utilising the by-products of carbon removal that abound throughout diverse supply chains, including fertilizer or carbonation for beverages, have been explored (Hepburn et al., 2019). In this manner, value-chain procurement stands out as another lever with which the private sector can potentially channel productive investment.

3.3 Beyond Inventory Levers

The majority of potential carbon removal investment opportunities lie beyond an entity’s greenhouse-gas inventory boundaries through the use of compensation and contribution levers. The former includes mandatory and voluntary carbon offsetting or procurement techniques, whilst the latter involves investments to catalyse removal potential.

3.3.1 Compensation Models

(4) **Compliance Obligations:** While entities are obligated to participate in compliance carbon markets, they now have increasing choices in how to fulfil their obligations under these mechanisms– providing another lever for carbon removal investment. Regulators in several jurisdictions are indicating flexibility in allowing the use of carbon credits in emissions trading schemes, which can potentially include removal projects (Fuss et al, 2024). Indeed, globally some 5 million carbon credits were surrendered in lieu of emissions trading scheme units for compliance purposes in 2022 (World Bank, 2023a: 39, 58). At the same time, some governments have already explored or are now exploring direct integration of carbon removal into their emissions trading schemes (Ministry for Primary Industries, 2023; Department for

Energy Security and Net Zero, 2024). Within this context, initiatives such as the European Union's Carbon Border Adjustment Mechanism and discussions about a global carbon price at the World Trade Organisation further indicate the potential expansion of compliance mechanisms as an avenue to put a cost on carbon (Reuters, 2023). In turn, such developments could drive private sector investment in carbon removal as a means of reducing net liability.

(5) **Reverse Auctions:** Reverse auctions have become a popular method for actors to identify suitable investment opportunities from the plethora of available carbon removal projects. This process involves issuing a request for proposals, where actors outline terms such as product types and conditions of interest. The content of these requests for proposals is crucial, as factors beyond price, such as terms, can significantly impact the commercialisation opportunities for innovative carbon removal types. Microsoft's reverse auction in June 2020 provides a leading example and garnered responses from 79 applicants covering 189 projects across 40 countries (Microsoft, 2021).[2] Reverse auctions can thus give a clear demand signal to project developers and in turn ensure that carbon removal investment is being effectively channelled in a way that best meets an organisation's needs.

(6) **Advanced Market Commitments:** Recent years have also seen the emergence of various advanced market commitments, illustrating yet another channel for private sector investment in removals. The Frontier consortium, led by payment processor Stripe, in 2022 spent $65.9 million contracting 131,091 tons of carbon removal from suppliers with a total commitment of $1 billion USD (Frontier, 2024). While Frontier tends to provide carbon removal project developers with relatively small volumes of funding (often up to USD $500,000), it is provided up front and not conditional on delivery, to catalyse growth in the industry which is itself still in its infancy. In April 2023, another sizeable advance market commitment of 193,125 tons of carbon removal was made by the Next Gen Facility, a joint venture between Southpole and Mitsubishi (Southpole, 2023). In May 2023, these volumes were again surpassed through a purchase by JP Morgan of 800,000 tons of carbon removal and a partnership between Microsoft and the Danish government-owned energy company Ørsted to purchase 3.67 million tons of carbon removal (Ørsted, 2024). Advanced market commitments can also be paired with transaction-funded models, whereby removals are purchased as and when a transaction occurs.[3] As a result, advanced

[2] This model has also been successfully tested by the public sector. See Lundberg, L. & Fridahl, M. The missing piece in policy for carbon dioxide removal: reverse auctions as an interim solution. *Discov. Energy* 2, 1–7 (2022).
[3] Examples include the Stripe Climate and the Climate Transformation Facility.

market commitments present a sizeable lever for private sector investment into carbon removal.

(7) **Voluntary Carbon Markets:** While carbon removal, particularly when novel, has made up only a minor share of the VCM to date in absolute volume terms, the VCM has played an important role in supplying catalytic investment which has the potential to drive more funding (Fuss et al., 2024). Most registries that facilitate trades of carbon credits offer carbon removal credits, and more recently, dedicated marketplaces to purchase novel carbon removal have also been established.[4] Despite the availability of carbon removal credits, the actual volumes traded openly on the VCM registries remain proportionally much less significant: Microsoft's novel carbon removal purchases in 2023 were 17x the sales of the largest novel market-based supplier Carbonfuture.[5] Even so, it is often carbon credit purchases mediated through the VCM which are the first port of entry for many entities into the world of carbon removal. The VCM also fulfils an important price-discovery function that the bilaterally dominated market for novel carbon removal does not. For these reasons, the VCM remains a useful lever for carbon removal investment by the private-sector.

3.3.2 Contribution Models

In recent years, there have been growing calls for the private sector to undertake beyond value-chain mitigation (SBTi, 2024). In the context of carbon removal, this avenue involves external investments into carbon removal projects without being linked to an internal carbon offsetting claim as the levers of catalytic finance and innovation funding reveal.

(8) **Catalytic Finance:** Corporations hold considerable influence as providers of catalytic funding when aiming to maximise the impact of each dollar spent on carbon removal without being tethered to an offsetting claim. However, evaluating whether such financing truly stimulates carbon removal requires a certain level of in-house expertise, a capability that many entities do not yet possess. The Milkywire Fund has emerged to address this gap for a broader range of private sectors, offering an evidence-based means for companies to voluntarily invest in novel carbon removal outside their value chain (Milkywire, 2024). This highlights that, while private investment in carbon removal has traditionally been associated with offsetting claims, the realm of contribution finance presents an alternative lever that can amplify the

[4] Examples include Puro, Super Critical, CUR8, Zopeful.
[5] This difference being 3,121,344 tCO_2 versus 180,156 tCO_2 respectively. CDR.FYI. (November 2023) https://www.cdr.fyi

climate impact of the investment — resulting in maximum sequestration per dollar invested.

(9) **Innovation Funds:** Contribution finance can also find application through targeted innovation funds, holding significant promise in the realm of novel carbon removal. These funds play a crucial role in expanding the ecosystem of available actors in the field. Innovation funds can be general or specific to certain types of carbon removal and may take various forms including direct grant-based funds or competition-based models. Microsoft, for instance, announced a $1 billion Climate Innovation Fund that focuses, in part, on supporting early-stage carbon removal ventures (Microsoft, 2023). In September 2023 HSBC also pledged investment of $1 Billion USD into climate technologies, including carbon removal (HSBC, 2023). The $100 million USD XPRIZE for Carbon Removal provides another notable example, with its competition-based model that seeks to boost the global supply of cost-effective, durable, carbon removal solutions (XPRIZE and Musk Foundation, 2023). Since the XPRIZE's launch some 1,334 project teams from 88 countries have participated, showcasing how innovation funds offer a flexible and creative channel for private-sector investment in carbon removal (XPRIZE and Musk Foundation, 2023). As a result, there are instances of a range of formats through which innovation funding can be channelled.

3.4 Impact of Deployment

Just as not all levers are created equal in terms of their potential to scale carbon removal, they intersect differently with the potential incentives that may attract investment. As Table 2 reveals, levers could be strongly connected to certain removal-investment incentives or by contrast have a very weak association. While it is not a precondition that a specific incentive should be at play to attract investment in carbon removal, it is likely that the levers which embed several incentives will have a higher likelihood of deployment.

Table 2: *The association between the carbon removal investment levers and carbon removal investment incentives*

Category	Impact
Negligible: • Potential: limited • Likelihood: low • Magnitude: small • Persistence: weak	There is a no clear association between the carbon removal investment lever and a particular investor motivation. For instance, the compliance markets lever is a compensation mechanism largely unrelated to the desire of some actors to make a climate contribution.
Limited: • Potential: possible • Likelihood: low • Magnitude: small • Persistence: weak	There is potential for a positive association between the carbon removal investment lever and a particular investor motivation, but the scope for this is limited. For instance, investing in removals via procurement practices could reduce your product's emissions and in turn potential compliance obligations could arise as a result of a carbon border-adjustment mechanism.
Moderate: • Potential: yes • Likelihood: medium • Magnitude: moderate • Persistence: variable	There is a positive association between the carbon removal investment lever and a particular investor motivation. For instance, acquiring a carbon removal company could provide an entity with a reputational boost.
Significant: • Potential: yes • Likelihood: high • Magnitude: medium • Persistence: strong	There is strong association between the carbon removal investment lever and a particular investor motivation. For instance, there is a strong connection between providing additional climate finance and efforts to protect and restore natural carbon sinks in and of their own right.

While the degree of association between a given lever and attendant investment incentive does not necessarily speak to its potential to generate carbon removal investment, it is useful to examine the nexus between the 12 investment levers and potential incentives more closely as Table 3 does.

Table 3: *Generalised association between carbon removal investment levers and carbon removal investment incentives*

	(1) Acquisition	(2) Stocks	(3) Bonds	(4) Products	(5) Insetting	(6) Procurement	(7) ETS Integration	(8) AMCs	(9) Reverse Auctions	(10) Carbon Markets	(11) Climate Finance	(12) Innovation Funding
Economic Opportunity	S	S	S	M	M	L	N	L	L	L	L	M
Business Advantage	M	M	M	M	M	M	N	S	N	M	N	N
Reputational Reward	M	L	L	S	M	L	N	S	M	L	S	S
Min. Reputational Risk	L	L	L	M	S	L	L	M	M	L	L	L
Compliance Requirements	N	N	N	L	L	L	S	N	N	L	N	L
Restoring Nature	L	L	L	L	M	N	N	L	L	M	S	N
Research & Development	L	N	N	L	L	L	N	L	M	L	L	S
Social Licence	L	L	L	L		L	N	M	M	L	S	S
Climate Contribution	N	N	N	L	L	L	N	M		L	S	M

Table 3 reveals a generalised overview of the interdependencies between a carbon removal investment lever and incentives which could, in turn, help shape carbon removal investors' preferences. It reveals that some investment levers are linked to a greater range and depth of incentives. Of course, determining the exact interplay between the investment levers and applicable incentives requires further contextualisation within a given organisational and regulatory environment. Although beyond the scope of this working paper, further research to quantify the impact of each lever on the overall volume and quality of carbon removal deployment should also be considered. It is likely, for example, that the use of carbon removal units to meet a compliance obligation presents one of the levers with the largest potential for deployment, particularly of more durable forms of carbon removal (Fuss et al., 2024). At the same time, there will necessarily be a limit on actors' ability to integrate carbon removal into their physical or financial products. All in all, this comparison illustrates that just as not all forms of carbon removal are created equal, neither are the potential levers to stimulate investment in it, both from an incentives and potential-impact standpoint.

3.5 Summary

While carbon removal investment is typically framed within the context of offsetting via the VCM, this section has revealed that in fact that is only one of twelve levers that the private sector can deploy. While the levers explored are neither equal in their potential nor their applicability to certain types of entities, the menu of options the typology presents illustrates how the private sector actors can build a carbon removal investment strategy bespoke to their own circumstances that maximises upsides whilst limiting risks.

4. Emerging Dynamics

Part 3 explored the manifold ways that private-sector actors can invest in carbon removal. Yet it is equally important to note that such decisions occur against an array of emerging dynamics that will continue to shape the removal-investment ecosystem on both a product and systems level, from the standards landscape to the harmonisation of carbon markets and innovations.

4.1 Standardisation of Quality

Given that removal projects tend to generate credits relied on for offsetting purposes, ensuring quality is critical. To help determine this, investors need to be able to distinguish carbon removal projects from other forms of emissions reduction or avoidance. It is also essential that one can identify the type of carbon removal project to understand its unique profile of co-benefits and risks, including reversal where carbon re-enters the atmosphere. Yet it is often difficult for the private sector to have the necessary accurate information. Standards to help guarantee quality from both the supply and demand side are beginning to change this picture.

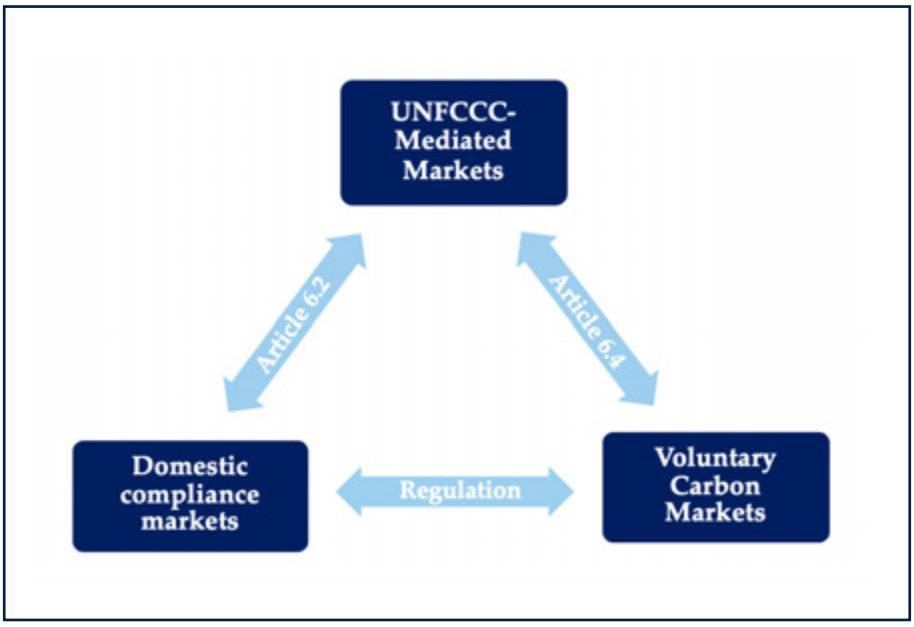
From the supply side, several developments remain crucial. The 2023 release of the Core Carbon Principles (CCPs) to provide a benchmark to assess the quality of carbon credits is a leading example. Having been developed by the Integrity Council for the Voluntary Carbon Market, the ten CCPs describe aspects from additionality through to permanence (ICVCM, 2023). It is not yet clear to what extent current carbon credit projects, which can include carbon removal but go beyond it to other forms of emissions avoidance and reduction projects, adhere to the CCPs. Nevertheless, it is clear that CCP-compliant credits have attracted a price premium in contrast to their competitors, which should in turn incentivise increased quality of supply from project developers.

There have also been several developments on the demand side to standardise quality. In 2023, the Voluntary Carbon Markets Integrity Initiative published its revised Claims Code of Practice to assist companies with making transparent and credible claims about their net-zero target progress (VCMI, 2023). In 2024, the University of Oxford released the Revised Principles of Net Zero Carbon Aligned Offsetting, outlining how purchasers should seek to transition to permanent carbon removal over time to reach net zero (Axelsson et al., 2024). There are also emerging contribution-based models, for instance, the Science Based Targets Initiative's work on beyond value-chain mitigation (SBTI, 2024). As a result, there is

increasing attention being paid to demand-side claims, and how they can help drive investment into climate mitigation, including carbon removal.

4.2 New Market Horizons

In tandem with the increasing emphasis on standards, there is also emerging convergence between various market mechanisms which could enhance the value of carbon removal investment by driving scale and demand. The convergence of carbon markets through harmonisation stands out as a significant emerging dynamic with profound implications for the future of carbon removal. Box Three outlines three key channels through which this convergence could materialise, showcasing the potential links between international, transnational and domestic aspects of carbon markets in the form of Article 6, the VCM, and compliance markets respectively.



Box three: Levers for Carbon Market Convergence

Commencing with Article 6.2 of the Paris Agreement, countries are empowered to establish direct partnerships for the international transfer of “mitigation outcomes”, encompassing those generated through carbon removal projects. Countries such as Switzerland and Singapore are actively forging bilateral memorandums of understanding and are implementing pilot projects (UNEP, 2024). While no pilot projects are for carbon removal,

there are indications that this will change, for instance, Sweden and Switzerland concluded an agreement to bilaterally test the trade of novel carbon removal credits (Swedish Energy Agency, 2023). Article 6.4, on the other hand, facilitates the voluntary trading of Article 6.4 emissions-reductions and mitigation-contribution units, offering a centralised mechanism for trade and investment in carbon removal projects.[6] However, the ability for Article 6.4 to act as a conduit for removal investment presently remains uncertain, given the outcome of COP28 where Parties rejected further guidance on its operationalisation, including specific guidance on removals (Johnstone and Resendiz, 2024). In parallel we are also seeing harmonisation between compliance and voluntary market mechanisms within a given jurisdiction, allowing credits from the former to be used for meeting compliance obligations (National Environment Agency, 2023). The emergence of new market horizons at these points of convergence has the potential to better join up the fragmented and opaque nature of the VCM, paving the way for further confidence in carbon removal investment.

4.3 Innovations

Innovation on both a product and systems level is also a feature of the carbon removal investment landscape.

- Products: The potential for carbon removal deployment enables the development of innovative products. Prosets are one such example. A shorthand for “progressive offset”, prosets are defined as a “financial instrument that allows the purchaser to compensate for the impact of CO_2 emissions from fossil fuel use by committing an equivalent quantity of CO_2 to a combination of higher and lower-durability storage, increasing progressively over time” (Mitchell-Larson and Allen, 2022). The proset model helps minimise the risks of engaging in new and uncertain carbon removal types through a portfolio-based approach to carbon removal attuned to differing levels of ambition and price points, meeting demand for a net zero aligned offsetting product.[7] In future, there may also be the potential for a “proset+” product that could incorporate a package of normal carbon removal proset for residual hard-to-abate emissions, in addition to a top-up of sectoral decarbonisation projects such as sustainable aviation, or sustainable maritime, fuel credits. As a result, prosets are an example of a new market horizon innovation, which can make carbon removal investment both more accessible and net-zero aligned in future.

[6] In this way, Article 6.4 is similar to the Clean Development Mechanism under the Kyoto Protocol.
[7] At the time of writing CIX-Puro is planning on launching a world-first pilot of a proset. See Climate Impact X (6 June 2022). *Climate Impact X and Puro.earth partner to bring new net zero aligned carbon credit portfolio to market*.https://uploadsssl.webflow.com/641b1194b8c5208184a7126e/641b1194b8c52027baa7153b_Media%20release%20-%20CIX%20and%20Puro%20strategic%20partnership.pdf.

- Carbon Credit Rating Agencies: As new products and projects come to market there is an attendant need to ensure their quality. The first such carbon credit rating agency emerged in 2008, yet soon after dissolved due to a lack of demand (Harvey, 2008). Since 2020 a number of new carbon credit-rating agencies (CCRAs) have emerged. These tend to follow the same style by assigning projects a rating between A-D based on a number of unique factors. Such designations provide decision-useful information for both the supply-and-demand side of carbon removal investment, signalling which are most valuable. Some CCRAs like Pachama and Renoster focus on nature-based solutions, whereas others like Be Zero, CalyxGlobal and Sylvera review a broader portfolio of credits (Carbon Markets Watch, 2023). Whilst the innovation of CCRAs yields promise, they are often constrained to determining the quality of credits in an ex-post manner which can make them less tractable vehicles for assessing the quality of novel carbon removal credits which are often issued ex-ante, though this is beginning to change (Be Zero, 2023). To support the quality of these ratings there is an increasingly sophisticated range of technologies now able to support accurate monitoring, verification and reporting, such as machine learning, artificial intelligence and satellite technology. As an example of systems-level innovation, CCRAs play a vital role in addressing the information asymmetry present between carbon removal developers and private sector investors, helping to redirect capital towards high quality projects.

- Insurance: Complementing the pipeline of new products and ratings lies the new market for insurance to insure against “atmospheric default” (Johnstone, 2023). As a tool to de-risk investments, insurance can assist on both sides of the coin demand-and-supply side parts of the equation (Johnstone, 2023). Potentially insurable risks emerge at a number of junctures in generating carbon removal — ranging from the risk that a future removal will not be delivered to the risk that the CO_2 or other greenhouse gas it has captured is re-released. Supply-side insurance provides financial institutions with more leverage to be able to bring carbon removal-based credits onto their balance sheet. On the demand side, insurance can help to provide surety as to any claims backed by carbon removal investment, including offsetting. To address the emerging gap in this regard, both incumbent and new insurers have been developing offerings in this space (Kita, 2024; Oka, 2024). As a result, the advent of carbon credit insurance is a clear demonstration of the complementary tools that are becoming available to minimise the risk that carbon removal investment carries, particularly when used for offsetting purposes.

4.4 Summary

As this section has highlighted, increasing standardisation, new market horizons and product and systems innovations all stand to affect the carbon removal investment landscape. Bearing them in mind therefore can help the private sector grasp the current investment prospects into carbon removal whilst also being primed for its future shifts.

5. Conclusion

Carbon removal is indispensable for achieving net-zero goals, and immediate investment in supply is essential to meet future demand. To facilitate this, a multi-pronged approach to drive private investment into carbon removal is needed. There are many reasons why the private sector should consider investing in carbon removal to yield both commercial and climate benefits. Indeed, examples abound in this working paper of the private sector setting net-zero targets and investing in carbon removal both within and outside their value chain as part of this strategy. While entities' efforts to offset their residual emissions have propelled substantial share progress to date, relying solely on these sources is insufficient to scale carbon removal investment to the levels needed in future. Instead, private-sector actors should consider employing a wider range of complementary strategies that align with and maximise the opportunities from emerging public-sector investment. These levers can include investing in removal capacity by channelling investment into carbon removal entities, establishing removal-based projects, and contributing catalytic climate finance. At the same time as these opportunities exist, they will be shaped by overarching and emerging trends of standardisation, market convergence, and innovation which continue to reshape the broader carbon removal investment landscape. Further research is needed both to quantify the potential role of these levers on the quantum and quality of carbon removal development and to explore the interrelationships between these private-sector levers and their public-sector equivalents (Hickey et al., 2023). Even so, it is already clear that private-sector actors ready to embrace these levers will be best positioned to meet the challenges of net-zero transition: minimising its risks whilst capitalising on the economic opportunities it presents.

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