Potsdam Institute for Climate Impact Research
KfW Research

Let it sink in: New governance and finance structures are needed to scale up carbon dioxide removals

11 November 2024

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Executive Summary

- **The world is most probably going to overshoot the available carbon budget for 1.5°C**. Given the continued rise in global CO_2 emissions, the inertia of social and political systems and the lock-in effects caused by previous investment decisions, global efforts to phase-out fossil fuels and reduce emissions in line with the Paris Accord remain insufficient.
- **Climate change comes at a substantial cost. Greenhouse gases emitted to date will reduce global income by an estimated 19% until 2050 compared to a scenario without climate impacts.** If emissions continue to rise, climate damages will further escalate in the second half of the century, potentially causing social costs to the order of USD 1,000/t CO_2 and higher.
- **Carbon dioxide removal (CDR) is emerging as a crucial new pillar of climate policy. It is essential for achieving net-negative emissions** and effectively managing temperature overshoot. Traditional strategies focused solely on emission reductions and adaptation are insufficient to address the scale of the climate crisis.
- **The financial requirements for scaling CDR technologies are enormous, with estimates suggesting that global expenditures could reach annually up to 2% of projected global GDP by 2050.** This financial burden is likely to overstretch public budgets, especially for countries with limited fiscal flexibility, and thus calls for involvement of private sources of capital. Yet, such costs pale in comparison to the financial burden imposed by climate damage.
- **Extending carbon markets for net-negative emissions is a promising option for leveraging private finance.** One way to create demand for removals is to introduce a new type of carbon market certificate: so-called “clean-up certificates”, which represent an obligation to remove a ton of carbon in the future. To manage associated risks of impermanence and liability and to ensure quality standards, market ramp-up needs to be paralleled by an adequate institutional setting, which in the EU could include a European Carbon Central Bank and a certification authority.
- **Many novel CDR solutions are currently still under development or in the demonstration phase.** While cost reductions due to technological progress and economies of scale are likely to be realised, complementary instruments such as support for R&D and investment incentives can help to bring novel CDR technologies to market maturity in a timely manner.
- In light of the COP29 thematic backdrop, **this article outlines five priority fields of action: (1) Adapt carbon markets** to support net-negative emissions, **(2) Expand market coverage** to include more countries, **(3) Support innovation and investment in CDR technologies**, **(4) Establish a CDR buyers' club** to ensure demand, and **(5) Operationalise Article 6 of the Paris Agreement** to enable the international transfer of carbon credits, while ensuring robust environmental and social safeguards.

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1. The economic costs of climate change and the need for additional action

1.1 Temperature targets, carbon budget and overshoot

COP29 is the second of three consecutive summits that together pursue the "Roadmap to Mission 1.5°C", a Presidential initiative intended to enhance international action in order to keep 1.5°C within reach. This presents policy makers with a critical opportunity to focus on the long-term requirements for achieving the 1.5°C target. Such efforts involve a discussion on the key pillars of climate action, as well as on an enabling policy environment. To make well-informed next steps, these discussions should start by assessing the implications from the remaining carbon budget.

The atmosphere has a limited capacity to absorb greenhouse gases. As every increase in atmospheric CO_2 concentration contributes to further warming, only a finite amount can be absorbed before global mean temperature levels rise above Paris-compatible thresholds. Most recent estimates indicate that the remaining carbon budget to hold global warming well below 2°C is 750 to 900 Gt CO_2 (Forster et al., 2024).[7] To keep warming at 1.5°C with a 50% likelihood, no more than another 200 Gt CO_2 may be emitted from the beginning of 2024 onward.

The tightness of the remaining atmospheric carbon space becomes evident when compared to the amount of CO_2 that is embodied in the world's fossil fuel resources.[8] To prevent further escalating climate risks, the majority of these resources must remain unburnt.

However, global efforts to phase out fossil fuels and reduce emissions in line with the Paris Accord are still insufficient. While the first Global Stocktake – concluded at the 2023 UN Climate Conference in Dubai (COP28) – formally called for a shift away from coal, oil and gas, the energy and climate policies of most countries remain misaligned with this objective (UNEP, 2024).

Given the continued rise in global emissions, the inertia of social and political systems and the lock-in effects caused by previous investment decisions, the world is most probably going to overshoot the available carbon budget for 1.5°C. It is very likely that the 1.5°C threshold will be exceeded – at least temporarily – within this decade. There is virtually no IPCC scenario that meets 1.5°C with no or low overshoot relying only on realistic assumptions about future developments (Warszawski et al., 2021). This insight has two fundamental implications. Firstly, the international community needs to prepare for deliberately managing the temperature overshoot through net-negative emissions. Secondly, the world is facing severe damages from climate impacts. To mitigate the resulting risks, the international community needs to swiftly phase out fossil fuels and lower greenhouse gas emissions. In addition, countries should step up adaptation efforts to mitigate at least some of the projected damages.

1.2 Economic damages from climate change and the Social Costs of Carbon

The costs of climate damages already materialise today and are expected to rise in the future. Accounting for regional damages from changes in temperature and precipitation, a recent analysis finds that the world is committed to an income reduction of 19% within the next 26 years relative to a baseline without climate impacts (Kotz et al., 2024a). The committed damages are defined by historic emissions and socioeconomic inertia and are thus independent of future emission choices. If emissions continue to rise, climate damages will further escalate in the second half of the century.

Significant income reductions are expected across most world regions, including the United States and Europe. However, the largest damages are projected for tropical countries in South Asia, South America, and Africa, primarily through channels affecting economic growth, such as climate change impacts on agricultural yields, labour productivity and infrastructure (Kalkuhl & Wenz, 2020; Kotz et al., 2024a).

The projection of future climate damages also highlights the economic value from emission reduction. In fact, mid-century damages already outweigh the mitigation costs required to limit global warming to 2°C by sixfold (Kotz et al., 2024a). As a matter of fact, every additional ton of CO_2 causes tangible economic costs. The marginal costs of a metric ton of CO_2 are known as the Social Costs of Carbon (SCC). Recent estimates suggest that the SCC are likely much higher than the values found in previous literature and used in policy making (EPA, 2023). Considering different impact channels, an aggregate effect on the economy and a lower-bound estimate of the persistence of damages considerably raises the SCC estimates. At present value terms and applying a discount

[7] This span indicates the carbon budget available as of the beginning of 2024 to hold global warming at 2°C with a likelihood of 83% and 67%, respectively (Forster et al., 2024). A likely (greater than 66%) chance of meeting 2°C is a common interpretation of the "well-below 2°C"-goal (Schleussner et al., 2022).

[8] If all identified and estimated global coal, gas and oil resources were extracted and combusted, this could cause CO_2 emissions of around 10,600 to 49,200 Gt (BGR, 2024; Welsby et al., 2021). This span includes secured reserves as well as contingent and prospective ("yet-to-find") resources. The upper and lower bound refer to different estimates of the coal resource base. The estimates for oil and gas resources are largely consistent between different sources.

rate of 2%, a recent estimate indicates SCC of USD 1,065/t CO_2 (Bilal & Känzig, 2024) – much more than the highest carbon price applied today. Emerging research even points to figures more than twice as high (Kotz et al., 2024b).

Real losses may even be higher as these estimates only include some climate impact channels and do not account for non-market effects such as increased mortality and biodiversity losses. The SCC are thus well above most reasonable mitigation costs. These results reveal two important principles that should guide future policy making: First, the impacts of climate change represent a severe threat to long-term growth and economic prosperity, let alone to human well-being, human lives and the integrity of ecosystems. Therefore, climate policy is a crucial lever for securing future economic prosperity, in addition to being pivotal in preventing escalating existential threats. Second, the real costs of emissions should be reflected in climate policies.

2. CDR as new pillar of climate policy

2.1 A game changer has emerged

The two traditional pillars of climate policy – emission reduction and adaptation – are essential for managing the climate challenges ahead, yet they are insufficient on their own. While “deep, rapid and sustained” (IPCC, 2023) emission reductions are crucial to minimise systemic risks and avoid overreliance on unestablished, expensive technologies (Schleussner et al., 2024), additional abatement becomes prohibitively costly as the economy approaches zero emissions (e.g. Knopf et al., 2011). Most notably, however, mitigation alone cannot achieve net-negative emissions, which are decisive for reversing any overshoot of the global mean temperature targets. Adaptation may help to reduce climate-induced costs but its effectiveness is bound by constraints in the option space available (Thomas et al., 2021). Furthermore, there are distributional issues with adaptation because those who are hit the hardest typically have the lowest adaptive capacity. While mitigation and well-guided adaptation are essential, their shortcomings call for complementing any credible climate policy strategy by a third pillar: carbon dioxide removals (CDR). That being said, removal options are not a silver bullet to tackling climate change and, thus, an optimal mix will require decisive action across all climate strategies.

The emergence of CDR methods is fundamentally reshaping climate policy – positioning carbon removals as a true “game changer” (Edenhofer, 2024; Edenhofer & Kalkuhl, 2024). First, only by deploying CDR at scale can the international community achieve net-negative emissions to effectively manage the temperature overshoot. Second, CDR reduces the cost of climate action by introducing both sectoral and temporal flexibility, making even ambitious climate targets attainable over time. This also increases the political feasibility of the Paris targets. Third, carbon removals open new avenues for international cooperation, potentially creating momentum for future climate negotiations. Deploying CDR at scale requires advancing the institutional framework of climate policy, particularly carbon markets, to ensure that net-negative emissions – essentially representing a public good – are financed through private or blended finance mechanisms.

2.2 CDR options

There are various CDR methods which are based on different ways to capture and store CO_2. These methods are at different stages of technological readiness. Virtually all of today’s removals result from so-called conventional CDR. These are well-established practices that are to a large part reported under countries’ Land Use, Land Use-Change and Forestry (LULUCF) activities. Conventional CDR either stores carbon in the biosphere – principally through afforestation, reforestation, agroforestry and forest management, peatland and coastal wetland restoration, and soil carbon sequestration – or in the built environment through durable wood products (Smith et al., 2024).

However, following several future scenarios, these conventional methods – while remaining essential – will be insufficient to meet the required amount of CDR. Novel methods, which generally are at a much earlier stage of development, are needed to complement the portfolio. There is a wide array of novel methods, which rely on different storage sites. One option is to directly sequester carbon from the atmosphere with air filter systems and storage in geological formations. Such Direct Air Carbon Capture and Storage (DACCS) technologies are currently under research and only few DACCS plants are being operated (IEA, 2024). Another option for novel CDR with geological storage is Bioenergy with Carbon Capture and Storage (BECCS). Other approaches based on different storage sites include enhanced weathering, ocean alkalisation and biochar.

The different conventional and novel CDR methods are not “born equal” (Strefler et al., 2021). Besides their technological readiness, they also differ in their (regional) potential, economic costs, potential side-effects (e.g., with regards to biodiversity conservation or food and energy security) and the durability of storage (Table 1). Carbon storage in geological formations via BECCS and DACCS can last for millennia, making it effectively permanent

(Smith et al., 2024). Conventional CDR methods are generally regarded as less permanent, with storage durations typically ranging from years to centuries. Carbon storage in the biosphere is especially vulnerable to reversal. Generally, CO_2 is released back into the atmosphere when forests, wetlands, or peatlands experience natural disturbances, as well as when they degrade or are converted. Poor management practices as well as escalating climate risks and extreme events (such as wildfires or droughts) accelerate leakage of sequestered carbon.

Table 1: Summary of carbon dioxide removal options

Option	Type	Carbon storage pool	TRL [1–9]	Potential [$GtCO_2$/yr]	Costs in 2050 [$/$tCO_2$]	Storage duration [half-life]
Soil carbon sequestration	Conventional	Built environment	8–9	0.6–9.3	0–100	Years to decades
Re-/Afforestation	Conventional	Vegetation, soils & sediments	8–9	0.5–10	0–240	Decades to centuries
Biochar	Novel	Vegetation, soils & sediments	6–7	0.3–6.6	10–345	Decades to centuries
Ocean alkalinisation	Novel	Minerals	1–2	1–100	40–260	Centuries
Enhanced weathering	Novel	Minerals	3–4	2–4	50–200	Centuries
BECCS	Novel	Geological formations	5–6	0.5–11	15–400	Millennia
DACCS	Novel	Geological formations	6	5–40	100–300	Millennia

Note: TRL=technological readiness levels (from 1 to 9=operationally proven system); global potentials in $GtCO_2$ per year; economic cost in dollars of today's purchasing power per ton CO_2; all estimates for 2050; storage time in half-life. Based on CDR.fyi (2024); Edenhofer et al. (2023); Fuss et al. (2018)[9]; Hepburn et al. (2019); Hiraishi et al. (2014); Lehmann et al. (2021); Pathak et al. (2022); Smith et al. (2006); Smith et al. (2023); Smith et al. (2024); Woolf et al. (2021).

If carbon is released from storage, the removal process must be repeated. This creates a "carbon debt" that requires repayment. For CDR options with short storage duration, this turns into an ongoing cycle of removing and storing carbon that resembles Sisyphus's eternal task of pushing a rock uphill only to watch it roll back down (Franks et al., 2024). Still, the use of CDR with short storage duration remains a reasonable instrument from a macroeconomic perspective and creates several important co-benefits such as increased biodiversity. It helps smooth out the intertemporal costs of the transition and serves as a temporary bridge when more permanent solutions are not yet scalable or economically viable (ibid.).

A CDR portfolio approach would unlock scale, balance costs and uncertainties and hedge associated risks. Pursuing a diversity of CDR methods allows each world region to contribute according to its unique potential (Strefler et al., 2021). A broad portfolio can mitigate investment risks across projects and geographies and avoid sustainability concerns, resulting from over-dependence on any single CDR option. This is particularly important for bioenergy-based solutions, where rising demand could strain land and ecosystems without the implementation of robust land management policies, including pricing mechanisms (Merfort et al., 2023).

2.3 Addressing the CDR finance gap

CDR deployed today overwhelmingly occurs via conventional strategies. More than 99.9% of the current removal capacity, which totals around 2.2 Gt CO_2, comes from conventional CDR, largely constituted by forest-based removals. The market for novel CDR credits is still in its infancy but has displayed rapid growth in recent years. Current estimates indicate that funding commitments for novel CDR projects totaled USD 1.6 bn, equivalent to 7.2 Mt CO_2 in the past 12 months, up from only USD 0.2 bn or 0.4 Mt on average in 2021–2022 (see chart 1).[10] Cumulatively, nearly 12 Mt CO_2 have been sold thus far. Only a small fraction of these purchases has reached delivery stage, though (CDR.fyi, 2024). Due to their scalability, the CDR removal methods BECCS, DACCS and biochar currently account for the largest share of novel supply, while other innovative methods require even more piloting. On the demand side, purchases of carbon credits have thus far been concentrated on few tech companies and other corporate investors (CDR.fyi, 2024; Smith et al., 2024).

Financial needs for CDR are substantial. Funding flows from voluntary markets so far cover only a fraction of what is needed to deploy future CDR. Emission reductions projects dominated the voluntary carbon market (VCM) in 2022 and 2023. By contrast, CDR credits accounted for only slightly above 10% of total credits sold in the VCM. At present, the bulk of CDR facilitated through VCM is conventional rather than novel CDR. Yet, the nascent

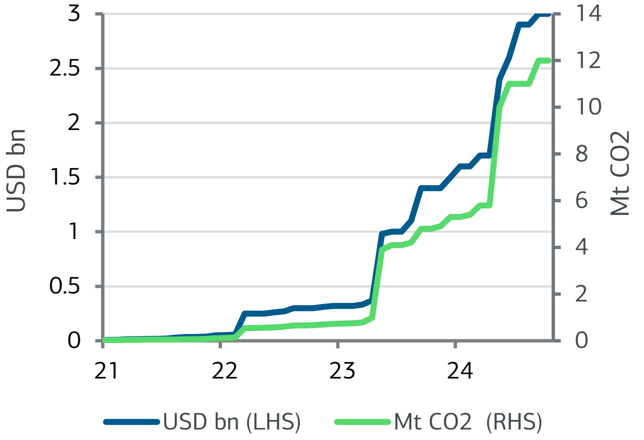
[9] The potentials given in this source are based on bottom-up literature and are thus non-additive.

[10] Covers market commitments for durable CDR incl. MOUs and purchases incl. pre-purchases, spot purchases and offtake agreements.

market for novel CDR is expanding, and with integration of CDR in compliance markets still pending (see chapter 3.1), the VCM remains a main driver of novel CDR scale-up (Fuss et al., 2024).

Bridging the CDR finance gap requires a sense of urgency to ensure sufficient long-term demand for removals to reach net zero. According to IPCC's net zero scenarios, more than twice of today's conventional CDR is needed in 2050. Novel CDR technologies will even have to rise exponentially (see chart 2). Corresponding global expenditures can be expected to reach roughly between 0.5 and 2% of projected global GDP in 2050.[11] This financial burden is likely to overstretch public budgets, especially for countries with limited fiscal flexibility, and thus calls for involvement of private capital sources.

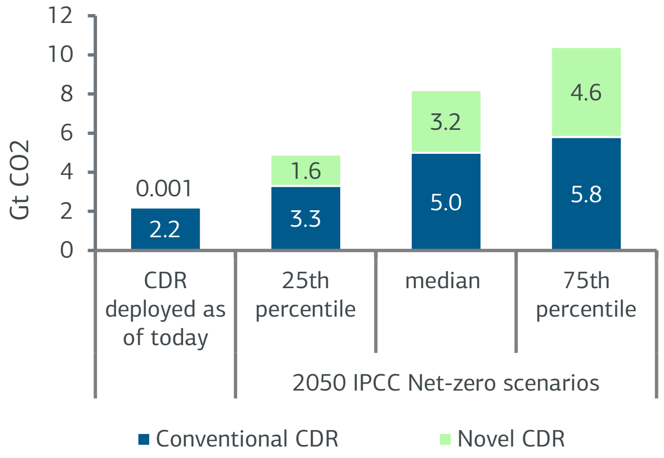
Chart 1: Funding commitments for novel CDR have picked up from infancy levels in recent years



Note: Total funding commitments accumulated over time.

Sources: CDR.fyi (2024), KfW Research

Chart 2: Novel CDR technologies will have to reach gigaton scale in 2050



Note: Median of Paris-relevant scenarios limiting global warming to 2°C or less. See Smith et.al. (2024) for scenarios exploring alternative paths beyond those calculated by IPCC.

Sources: Edenhofer et al. (2023), Smith et al. (2024), KfW Research

Many novel schemes are faced with high cost and uncertainty barriers. Short durations and payment upon delivery of typical offtake arrangements stand in the way for buyers to demonstrate sufficient risk appetite and commit to providing long-lasting capital. At the same time, significant initial investments are critical for lifting innovative technologies over time, while there is uncertainty about both the future cost of removal solutions and the volume of residual emissions (Alvera et al., 2022). In the last two years, the CDR market saw prices for DACCS averaging around USD 1,000/t CO_2 (Smith et al., 2024). This is substantially higher than current carbon market prices and thus a main challenge for scaling up novel technologies. Corporate purchases of removal credits in compliance and voluntary carbon markets can support the off-take and initiate market ramp-up, while it is essential that they complement emission reduction at the company-level. Depending on the profiles of the removal solutions, large upfront investments are needed throughout the remainder of this decade (e.g., in the case of conventional climate solutions) and sequentially to ensure future plant capacities (in the case of DACCS or BECCS).

2.4 Policy Instruments to support technology development

Investment security is needed to fill the finance gap and foster the development, scale-up and market integration of novel CDR. Policy and financial instruments that lever sufficient private capital are required. In the initial phase, public funding can share the risks of investments into the new, not yet viable technologies. However, to secure finance for CDR after the development phase, removals need to be made a viable self-sustaining business case. Policy instruments complementing carbon pricing mechanisms can accelerate the innovation cycle and guide promising, yet not commercially viable technologies to market maturity.

CDR methods differ in terms of technological maturity – which is crucial to identifying optimal policy approaches. Some CDR technologies, like enhanced weathering or Direct Air Capture (DAC), the cost intensive part of DACCS, are currently in an **early development stage** with rather low level of technological readiness.

[11] Assuming removal costs of USD100–300 per ton of CO_2 by 2050 and using the 25th to 75th percentile range of CDR deployment given in Smith et al. (2024) – covering the IPCC's C1–C3 scenarios and scenarios with no or higher contributions from novel and conventional CDR methods – global CDR deployment could reach approximately 5–10 $GtCO_2$ annually by 2050. This scale of deployment would correspond to annual global expenditures of USD0.5–3 trillion (or USD 0.6–3 trillion across the IPCC's C1–C3 scenarios). Global GDP was $93 trillion in 2023 trillion (World Bank, 2024a). A constant growth rate of 2% would lead GDP to around USD160 trillion in the year 2050, putting global CDR expenditures on the order of magnitude of roughly 0.5–2% of world GDP.

This involves researching the technology with its fundamental properties and expecting significant cost reductions as the technology matures. Due to high uncertainty about the technological and economic success of projects, it is difficult to finance such projects, so economic policy needs to step in. From the perspective of promotional policy, financial support approaches with high-risk assumption, such as grants and bonuses or tax incentives for R&D, are important tools already in use in some countries.

Other CDR technologies, like BECCS or biochar, have already moved closer to the **market introduction stage.** Yet even at this level of maturity, there is still considerable uncertainty, particularly regarding scalability and challenges tied potential side effects, such as land conversion impacts. State assistance in market development in the form of financial support for demonstration projects is an important type of aid, which could be carried out by means of promotional loans with a grant component or subsidies. Also, venture capital is an important pillar of financing at this stage, as new technologies are often embraced by newly founded businesses.

Policy instruments such as carbon contracts for difference (CCfDs) could support the deployment of CDR, by guaranteeing the purchase of specified quantities of carbon removal at a guaranteed price. In this case, the contract providers (e.g., governments) would agree to pay the difference between the guaranteed and the market price for the removal. This could help if CDR is uncompetitive due to low carbon prices or if large cost-reductions through upscaling are expected.

3. A market and regulatory framework for CDR

3.1 Carbon market integration

Extending carbon markets like the EU Emissions Trading System (EU ETS) to allow for net-negative emissions is a promising option to leverage private finance. Currently, emission trading systems cover 18% of global emissions and even more carbon markets are emerging worldwide (World Bank, 2024b). Transforming these markets into finance sources for removals may thus secure the future funding of removals within the EU and internationally. Making carbon markets fit for net-negative requires a paradigm shift, switching from determining the supply of emission certificates to stirring the demand for removals (Sultani et al., 2024). Thereby, carbon markets can play a vital role in managing the atmospheric carbon stock, even when the supply of regular emissions allowances reaches zero – a milestone envisioned for the EU's energy-intensive industry and energy supply sector by 2039 (Pahle et al., 2023).

One way to create this demand for removals is to introduce a new kind of carbon market certificate: so-called "clean-up certificates". These clean-up certificates would express a carbon debt – an obligation to remove a ton of carbon in the future (Lessmann et al., 2024). In such a system, companies that are regulated under the ETS could either buy regular emission permits or compensate their emissions by using a clean-up certificate that commits themselves to financing future removals. Those companies that anticipate future removal costs to be lower than current mitigation costs could thus opt to pay for removals instead of immediate emission reductions. This approach has three important benefits: Firstly, it would shift the responsibility to clean up emissions via carbon removal to the emitter. Secondly, the integration of clean up certificates in the ETS would help to find the efficient mix of emissions abatement and removal. Thirdly, by opening a new way for companies to meet their reduction obligations, it would enhance market flexibility. This could in turn lower the price of emission permits, thereby stabilising the market in the run up to net zero (Pahle et al., 2023). Importantly, a delay in emission reductions could be avoided if the cap of the ETS is adjusted accordingly, with each removal certificate replacing a regular emission permit. This would allow for increased ambition in emission reductions by tightening caps without driving up short-term abatement costs (Lessmann et al., 2024).

Reverse auctions could support and complement carbon market integration. In principle, it would be possible to adjust the conventional carbon budget such that cumulative emissions until the beginning of the net-negative phase are identical to the ETS with clean-up certificates. The regulator would need to earmark a certain fraction of the revenues from carbon pricing in the first phase for the financing of the net-negative phase. The regulator would also need to credibly commit to implementing the optimal net removal path, for example through reversed auctions on removals. This approach, however, may accelerate the time-inconsistency problem for the regulator as she has to pay for the removals in the last phase while withstanding opposition of firms and consumers against the high carbon price (Lessmann et al., 2024).

To regulate the carbon and removal market and address time inconsistency and liability issues, an update of the institutional framework is needed. If CDR is regulated through clean-up-certificates, a designated institution would need to address the risk of strategic bankruptcy of companies. Within the EU, a "European Carbon Central Bank" (ECCB) (Edenhofer et al., 2023) could take over this role. Through collateral deposits paid by the buyers of removal credits, the ECCB would address liability issues and act as a lender of last resort in case companies are unable to meet their removal obligations in the future. In the case of reverse auctions, institutional arrangements would need to bind the regulator to the payment obligation against a potential backlash from firms and consumers in opposition to high carbon prices. In addition, a certification authority could ensure the quality of removals with regards to their social and environmental integrity (ibid.).

The introduction of removals into compliance markets requires urgent action. Nearing adoption, the EU's Carbon Removal and Carbon Farming (CRCF) Regulation will establish a standardised certification system for carbon removals. In a subsequent step, opening compliance markets to removals could shape expectations in the CDR sector, thereby helping bridge the "valley of death" between innovation and market entry of emerging technologies. Moreover, in the case of clean-up-certificates, creating private demand for CDR by combining emissions overshoot allowances with the obligation to remove the carbon is only feasible while there are still companies regulated under the ETS.

3.2 New avenues for international cooperation

Countries in developing regions show particularly high potential for CDR. For example, reforestation is highly effective in tropical areas, where the capacity for carbon sequestration per hectare exceeds that of cooler northern regions. Similarly, BECCS is well-suited to regions like Latin America and Africa, while enhanced weathering benefits from the arable land available in warm, humid climates, giving regions like India and Latin America a comparative advantage. DACCS holds a cost advantage in regions with abundant geological storage capacity (Strefler et al., 2021). Kenya, for example, is currently exploring the development of large-scale DACCS projects (Climeworks, 2023).

On the demand side, advanced economies with ambitious climate targets may drive uptake of international carbon removals to compensate for residual emissions in hard-to-abate sectors. Concerns about economic competitiveness or the potential offshoring of industries to regions with less stringent emissions regulations may incentivise these countries to pursue durable carbon removals to substitute prohibitively expensive abatement options.

From a climate justice perspective, industry nations – bearing greater historical responsibility for emissions – could play a leading role in advancing demand for durable, high-integrity carbon removals. The EU, the US and smaller emitters have embedded net-negative commitments in their long-term climate strategies or legislation and aim to remove more carbon than they emit (European Union, 2021; U.S. Department of State & U.S. Executive Office of the President, 2021).

Bridging international demand and supply sides for carbon removal could create critical North-South channels for much-needed climate finance. However, robust environmental and social standards need to be embedded into these channels to function responsibly and equitably.

At UNFCCC level, a significant step towards minimising social and environmental impacts of carbon crediting projects is expected at COP29. Recent progress has been made regarding Article 6.4 of the Paris Agreement, related to the creation and trade of carbon credits. The "Sustainable Development Tool" (UNFCCC, 2023) could become a milestone to increasingly considering carbon removal under the aspect of international cooperation and aligning carbon market strategies with sustainable development priorities.

In light of these advancements, the EU could incentivise investments in high-quality carbon removals through cooperation on the basis of carbon market diplomacy and the Carbon Border Adjustment Mechanism (CBAM). Europe can share its extensive expertise in emission trading and carbon markets with international partners and can assist with technical assistance, technology transfer and financing support. Cooperation through carbon credits could provide a pragmatic solution, facilitating mutual recognition of climate efforts and potentially helping developing countries to comply with CBAM obligations (Delbeke, 2024).

4. Conclusions

The international community must prepare to manage the carbon overshoot, as the remaining carbon budget for limiting global warming to 1.5°C is likely to be exceeded within this decade. This reality necessitates the development of a new pillar of climate action: the active removal of atmospheric CO_2 through CDR. CDR, in conjunction with rapid mitigation and well-planned adaptation, allows for the deliberate management of the temperature overshoot through net-negative emissions, reversing climate risks and positioning it as a "game changer" in climate policy. Deploying CDR at the required gigaton scale will become a central task for policymakers in the coming decades. Key to this is the development of a robust financial architecture that supports the innovation, market integration and long-term funding of CDR methods.

COP29 in Baku provides a suitable platform for policymakers to lay the groundwork for an international finance and governance framework on CDR. With the implementation of the first Global Stocktake's outcomes, the alignment of international climate finance and the operationalisation of Article 6 topping the summit's agenda, many key issues are already on the table for discussion.

This paper gives five key recommendations to be considered in setting the course for an internationally coordinated CDR governance scheme:

1. **Make carbon markets fit for net-negative to catalyse private finance**
   With estimated financing needs in the order of roughly 0.5–2% of global GDP, funding of CDR would surpass the capacity of public budgets. Leveraging private sector funding is inevitable. While voluntary carbon markets can help drive innovation in the CDR sector, a more viable option is integrating CDR into carbon markets. Carbon markets adapted to net-negative frameworks also call for institutional advancement. In the EU, for instance, a European Carbon Central Bank could take a role in intermediating demand for and supply of carbon credits.

2. **Expand carbon market coverage**
   The EU's CBAM already incentivises several third countries to implement domestic carbon pricing schemes. The economic incentives set by CBAM could be accompanied by capacity building and diplomatic efforts. The EU's recently established Taskforce for Carbon Market Diplomacy is designed for this purpose and could become a key player in sharing knowledge and supporting the adoption of carbon markets in third countries.

3. **Support innovation and investment in CDR technologies**
   Today, many CDR technologies lack market maturity. At the same time, achieving the required mid-century CDR levels demands the immediate scale up of novel technologies. As a complement to the market framework for carbon removals, risk-adjusted incentive schemes can stimulate innovation and investments to facilitate technological development and market integration of novel CDR methods.

4. **Establish a CDR buyers' club**
   Given the high potential for CDR in developing regions, removals could form the basis of a new business model, creating economic opportunities for these regions. Industrialised countries could benefit from purchasing CDR credits of foreign origin to offset overshoot emissions or residual emissions from hard-to-abate sectors. These countries should consider forming a CDR buyers' club with specific quality standards to support the scale-up of high-quality CDR in developing regions. The club would signal secured demand and foster market confidence.

5. **Operationalise Article 6**
   Article 6 of the Paris Agreement is a vehicle to enable international transfer of removal credits. It may facilitate the trade of carbon credits from high-quality and additional removals between countries through bilateral or multilateral agreements. As a prerequisite, sound environmental and social safeguarding criteria need to be adopted and applied to removals.

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Appendix: Literature

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