Philanthropy Briefs

CARBON MANAGEMENT

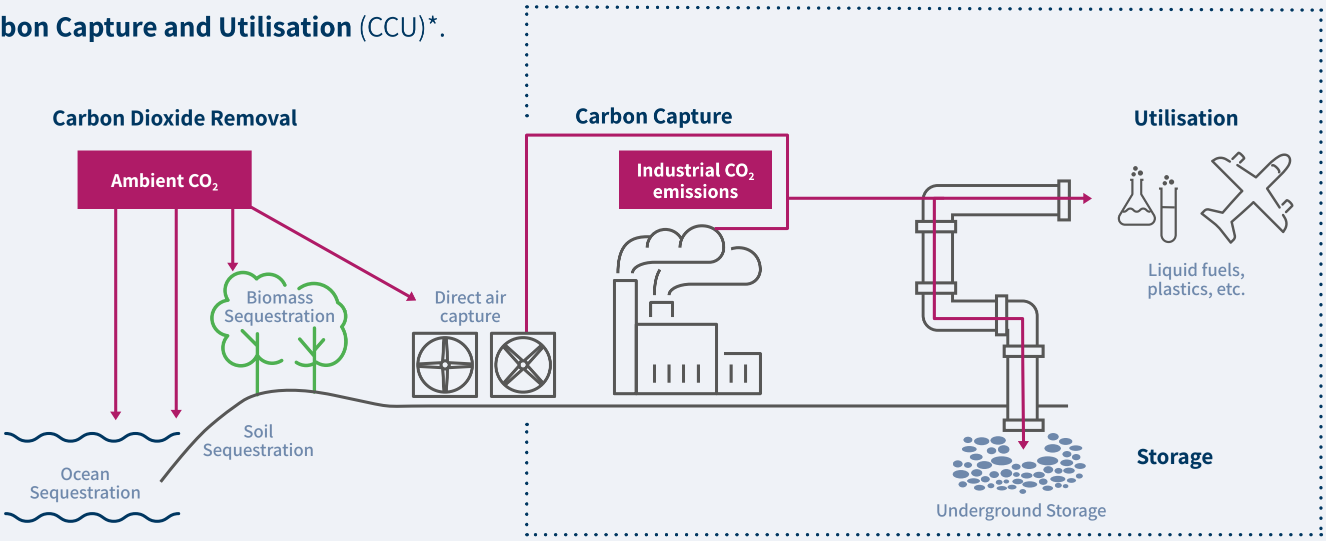
Primer

a series by
Active
Philanthropy

WHAT IS IT ABOUT?

Carbon management* is an umbrella term for a set of process chains that deal with greenhouse gas emissions by either **capturing** them **before** they are released or **removing** them **after** they've entered the atmosphere. These process chains can be structured in three distinctive strategies:[1]

- **Carbon Dioxide Removal** (CDR)*,
- **Carbon Capture and Storage** (CCS)*,
- **Carbon Capture and Utilisation** (CCU)*.



Components of Carbon Management. Adapted from Stanford University (2025)

Together, these strategies encompass processes to capture, store and/or use emissions at different stages of their life cycle.

WHY IS IT RELEVANT?

In order to halt climate change and become climate neutral, emission reductions remain the top priority, as they are the most effective and least costly path. However, carbon management is increasingly recognised as a necessary complement to climate mitigation, particularly in light of three challenges.

1. Even under the most optimistic mitigation scenarios, some emissions are expected to remain. These residual emissions* need to be counterbalanced to reach net-zero*.
2. Large volumes of greenhouse gases already in the atmosphere continue to drive global warming. These legacy emissions* have accumulated over time, because CO_2 and other greenhouse gases remain in the atmosphere for centuries (or in some cases even millennia) after being emitted.[2]
3. Most climate scenarios today project a temporary overshoot*, which refers to a scenario where global temperatures exceed the 1.5 °C target and consequently require future interventions to return below this threshold (even though some impacts of overshoot will be irreversible).[3]

Carbon management provides a toolkit to address these challenges: reducing and counterbalancing residual emissions, drawing down the legacy emissions that have accumulated in the atmosphere over time, and helping to correct temporary overshoot.

***For definition, see glossary in the annex**

[1] Schenuit et al. 2023, [2] US EPA 2015, [3] Reisinger 2025

Understanding the carbon management toolkit

The carbon management toolkit consists of three building blocks, that differ in purpose and function: CDR, CCS and CCU.

CDR is not a single technology, but a term that describes several human interventions with the common objective to remove CO_2 and durably store it in biomass, geologic formations, minerals, oceanic reservoirs or products. It is the only set of strategies that can reduce the stock of atmospheric CO_2 and deliver so-called negative emissions*.

- Counterbalance residual emissions
- Remove legacy emissions
- Correct for temporary overshoot by bringing emissions below net-zero

CCS refers to technologies that capture CO_2 at the point of emission – for example, from fossil-fuel power plants, cement factories, or hydrogen production – and store it underground in geological formations or former oil and gas reservoirs:

- Prevents new emissions from entering the atmosphere
- Reduce residual emissions from hard-to-abate sectors

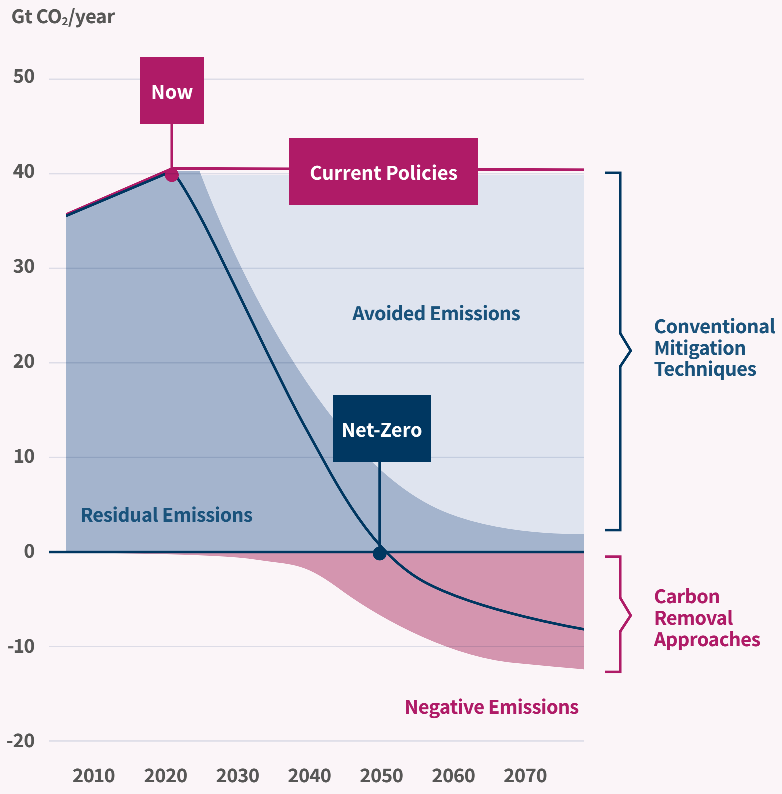
CCU refers to the use of captured CO_2 as a feedstock in industrial processes, e.g. for synthetic fuels, chemicals, or building materials. The carbon is only temporarily stored and gets re-emitted eventually:

- Delays residual emissions
- Offers limited climate benefit, as carbon is not durably stored

ZOOMING IN ON CDR

Removing carbon dioxide from the atmosphere is far more difficult and costly than preventing emissions in the first place. Yet because efforts to reduce and avoid emissions have been too slow and insufficient, the world now relies on large-scale CDR to help limit the worst impacts of the climate crisis.

As a result, all climate scenarios consistent with limiting warming to 1.5 °C now include substantial amounts of CDR. Estimates range widely, but a frequently cited benchmark suggests that 7-9 billion tonnes (Gt) of CO_2 will need to be removed annually by 2050[4]. The exact volume ultimately required depends on a carbon budgeting principle: the less we succeed in **avoiding emissions**, and the higher the volume of **residual emissions** we allow to persist, the more carbon dioxide will need to be removed from the atmosphere. In short, every tonne of avoided emissions today reduces need for CDR and reduces the burden passed on to future generations.



The pathway to achieving 1.5°C. Adapted from Systems Change Lab (2025)

CDR methods differ widely in terms of how carbon is captured, whether they are deployed on land or in marine environments, and where and how the carbon is stored. They also vary in expected removal potential, technological readiness, storage durability, and cost efficiency. While there is no universally agreed classification, CDR methods are often divided into conventional and novel approaches. ➜

***For definition, see glossary in the annex**

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[4] Smith et al. 2024.

ZOOMING IN ON CDR

Conventional CDR: Nature-based removals

Nature-based removals harness the natural ability of ecosystems to absorb CO_2 through photosynthesis and store it in biomass and soils. These interventions, such as afforestation, soil carbon sequestration and rewetting peatlands have long been deployed as climate solutions. Today, these methods account for almost all anthropogenic carbon removal, currently estimated at ~2 Gt (= 2 billion tonnes) of CO_2 per year[5]. They are typically less expensive, immediately deployable, and offer **co-benefits for biodiversity** and ecosystem services. However, their permanence* of **carbon storage is limited**, typically ranging from decades to centuries.[6]

Why can't we solely rely on nature-based removals?

Forests, mangroves, peatlands, oceans and other ecosystems are vital allies in climate action. They store carbon, support biodiversity, contribute to clean air and water, and build resilience to climate impacts. Yet from a sole carbon removal perspective, nature-based removals face limits. Carbon stored in trees or soils is vulnerable to reversal through droughts, wildfires or land degradation. Many solutions, like rewetting peatlands, take years to deliver results. Others, like afforestation, require vast land areas that may compete with food production. Nevertheless, nature-based removals are vital, but they cannot shoulder the amount of CDR needed alone.

In short, we must protect and restore ecosystems and develop hybrid and technological approaches with durable and scalable carbon sinks.

Novel CDR: Hybrid and technological approaches

Hybrid approaches enhance or accelerate natural processes to capture CO_2. This includes for example biochar, which converts biomass into a stable form of carbon applied to soils, and Ocean Alkalinity Enhancement (OAE), an approach that aims to increase the ocean's natural capacity to sequester CO_2 by adding alkaline substances.

Technology-based approaches rely on engineered systems to remove and/or store carbon. Examples are Direct Air Capture and Storage (DAC+S), which filters CO_2 directly from the ambient air, and Bioenergy with Carbon Capture and Storage (BECCS) which captures emissions from biomass-based energy production and stores them underground.

Currently, novel technology-based solutions and hybrid solutions are still **in demonstration phases** and account for only 0.1 % of total removals. However, they are expanding rapidly and are widely expected to play a growing role in future CDR portfolios due to their potential for long-term storage, with durations up to several millennia.[7]

The following table compares some of the most promising CDR approaches.**

	Nature-based removals			Hybrid approaches			Technological approaches	
	Afforestation	**Soil Carbon Sequestration**	**Peatland Restoration**	**Biochar**	**Enhanced Rock Weathering**	**Ocean Alkalinity Enhancement**	**DAC+S (Direct Air Capture + Storage)**	**BECCS (Bioenergy with Carbon Capture and Storage)**
								
	Growing forests to store atmospheric CO_2.	Agricultural methods to enhance carbon storage in soils.	Rewetting peatlands to store CO_2 and prevent emissions.	Converting biomass into stable biochar for soil carbon storage.	Applying silicate minerals to enhance natural CO_2 uptake.	Enhancing ocean chemistry to boost natural CO_2 absorption.	Filtering CO_2 from ambient air for permanent underground storage.	Plants absorb CO_2 while growing, are combusted for energy, and the CO_2 is captured and stored underground.
Potential	■■■■□	■■□□□	■■□□□	■■■■□	■■■■□	■■■■□	■■□□□	■■■■■
Technological readiness	■■■■■	■■■■■	■■■■■	■■■■□	■■□□□	■□□□□	■■■□□	■■■□□
Storage duration	■□□□□	■□□□□	■■□□□	■■■■■	■■■■■	■■■■□	■■■■■	■■■■■
Cost efficiency	■■■■■	■■■■■	■■■■■	■■■■□	■■■□□	■■■■□	■□□□□	■■■□□
Co-benefits*	■■■■□	■■■■□	■■■■■	■■■□□	■■■□□	■■□□□	■□□□□	■□□□□

A portfolio of CDR approaches. Adapted from DVNE 2025, complemented by own analysis

■□□□□	■■□□□	■■■□□	■■■■□	■■■■■
low	low-medium	medium	medium-high	high

** The evaluation of the categories is not definitive and should be understood as indicative and highly simplified. It offers a general overview of the strengths, shortcomings, and uncertainties of different approaches, drawing on available evidence and estimates from Smith et al. (2024), Mannion et al. (2023) and ESABC (2025).

***For definition, see glossary in the annex**

[5] Smith et al. 2024, [6] Herhold et al. 2024, [7] Smith et al. 2024

ZOOMING IN ON CDR

What's ahead of us

Scaling up CDR to the gigatonne levels by mid-century is an unprecedented global clean-up task. These fast facts illustrate the magnitude of the challenge.

7–9 billion tonnes

of CO_2 must be removed annually by 2050 – a mass so large it would make carbon removal one of the biggest material industries on Earth.[8]

10 million

jobs could be created in the carbon removal sector by 2050 – comparable to today's renewable energy workforce.[8]

1.5–2 billion

people's emissions would need to be removed each year – based on a global average of 4.7 tonnes of CO_2 per person.[9]

€ 5–14 trillion

in global investment in CDR is projected to be needed by 2050 to reach net-zero emissions.[10]

€ 940 billion

in annual revenue could be generated by the CDR industry by 2050 – rivalling the size of the global aviation sector.[11]

WHAT CAN PHILANTHROPY CONTRIBUTE TO GET THERE?

Creating demand and de-risking the CDR market:

Unlike other climate-relevant industries like renewable energy, carbon removal has so far no intrinsic market value. Rather, it is a public good for which demand must be 'artificially' created.[12] While voluntary carbon markets* (VCMs) built initial momentum, long-term viability will require integration into compliance markets where either governments purchase removals directly or oblige companies to do so.[13] However, compliance markets won't scale technologies that remain unproven, costly or hard to verify.

Philanthropy can help de-risk the market by funding early-stage demonstrations, advancing MRV* and certification standards, addressing regulatory uncertainty, and building confidence among early buyers.

The BMW Foundation Herbert Quandt published a practical guide for corporate leaders seeking to engage with carbon removal. The report outlines six building blocks for credible procurement: from raising internal awareness and building a business case, to budgeting and engaging the C-suite. By equipping corporate sustainability teams with structured guidance, the foundation helps reduce uncertainty and accelerate demand for carbon removals.

Accelerating political maturity and transparency:

Despite growing attention, carbon management and especially CDR remains politically underdeveloped. In Europe, for example, debates on integrating CDR into compliance markets are still evolving, and national frameworks for CO_2 transport, storage, and accountability are still nascent and fragmented. At the same time, there remains a widespread lack of societal understanding about the scale and complexity of the task.

Philanthropy can address this gap by enabling evidence-based debate and supporting pluralistic dialogue. In doing so, it can drive political maturity and help establish robust transparency frameworks. Both are critical to building legitimacy and public trust.

The Mercator Foundation supports the stakeholder dialogue series "Carbon Management – Negative Emissions" by think tank Zentrum Liberale Moderne, which convenes stakeholders from politics, academia, industry and civil society in Germany to foster a shared understanding of the role of carbon management in German climate policy.

***For definition, see glossary in the annex**

[8]Sartor et al. 2024, [9]Ritchie and Roser 2024, [10]Mannion et al. 2023, [11]Herhold et al. 2024, [12]Luck et al. 2024, [13]Lebling and Riedl 2025

THINGS TO CONSIDER FOR PHILANTHROPY

While carbon management may be inevitable for our race to net-zero, how it is governed, deployed, and justified remains deeply contested. Scaling carbon management at the pace and scale envisioned in climate scenarios will require navigating difficult trade-offs, scrutinising questions of justice and legitimacy, and avoiding the moral hazard of treating carbon management as a substitute for real mitigation. **Philanthropy now has a window of opportunity to ensure this field serves the public good.**

Discourse power and legitimacy

The more sectors are labelled as hard-to-abate, the more residual emissions we assume and the more we rely on carbon removal. Yet, discussions around residual emissions are often viewed through a technical lens, overlooking their political and social dimensions. Which industries are treated as immutable? Who bears the burden of removing emissions that wealthier societies opt to keep? These are decisions that far transcend the question of technical feasibility.[14] For instance, just 1 % of the global population accounts for half of all commercial aviation emissions.[15] Treating these emissions as unavoidable risks protecting luxury consumption and shifting the clean-up burden to others.

Philanthropy can support critical engagement with the assumptions behind CDR, investing in the knowledge and analysis needed to challenge them.

Building nuanced knowledge: The open-source book called "CDR Primer" supported by multiple philanthropies is a strong example of how philanthropic support can advance critical understanding of carbon removal. This resource frames CDR not just as a technical climate solution but as a social, political, and ethical issue. By offering accessible, multidisciplinary insight, the book invites broader public debate, establishes a common language and helps lay the foundation for governance rooted in shared values.

Place matters

From a sole climate perspective, it does not matter where carbon is removed, since CO_2 is evenly dispersed in the atmosphere. However, the social and ecological impacts of CDR deployment are highly local. Building a carbon management industry requires extensive infrastructure – from pipelines and industrial facilities to large areas of land for afforestation or other nature based approaches. This may create jobs but can also spark new conflicts over scarce resources such as land, water and clean energy.

Philanthropy can play a key role in grounding carbon management in justice principles from the start. This means supporting initiatives that amplify community voices, invest in robust environmental safeguards, and advocate for inclusive governance to ensure that the burdens of this emerging industry are not disproportionately borne by the most vulnerable.

Centring justice: Carbon180 is a US-based climate NGO working at the intersection of carbon removal and environmental justice. Largely philanthropy-funded, it advocates for policies that support the equitable scale-up of negative emissions technologies in the US and aims to embed justice and community voice in the design of future carbon removal frameworks. Similarly, a landmark report by Carbon Direct, supported by the McKnight Foundation, provides a first-of-its-kind baseline for understanding how CDR project siting intersects with environmental justice concerns in the United States.

Avoiding strategic misuse

One of the most pressing risks in carbon management is moral hazard: the idea that the prospect of future carbon removal and/or capture and storage is used to justify continued fossil fuel use or delay investments in cleaner technologies. The risk is especially acute in sectors like steel and concrete, which are currently at a crossroads[16]: invest in clean production now or risk locking in fossil-based systems that won't be replaced for decades.

Philanthropy can play a key role in safeguarding against this risk by promoting clear mitigation priorities and policy guardrails.

Supporting 'watch dogs': Carbon Gap, an entirely philanthropy-funded non-profit, is advancing policy tools to address mitigation deterrence in Europe. In a policy brief, it laid out a practical "mitigation hierarchy" that prioritises direct emissions reductions, clarifies the role of CDR, and offers concrete steps for policymakers to avoid locking in future dependence on removal.

[14] Nawaz et al. 2024, [15] Gössling and Humpe 2020, [16] Agora Industry 2021

GLOSSARY

Carbon Capture and Storage (CCS)

A process that captures CO_2 emissions at the source of generation and stores them in geological formations. It doesn't remove existing CO_2 but prevents new emissions from reaching the atmosphere. Climate benefits depend on the source of the captured CO_2 and the storage method: some projects have been used for Enhanced Oil Recovery, prolonging fossil fuel extraction, while others, such as Carbfix in Iceland, achieve permanent storage by mineralising the CO_2, avoiding such risks.

Carbon Capture and Utilisation (CCU)

Similar to CCS, but instead of storage, captured CO_2 is used to make products (e.g. fuels, chemicals, or building materials). The climate benefit depends on whether and how long the CO_2 is stored.

Carbon Management

An umbrella term that encompasses all strategies to handle greenhouse gas emissions by either capturing them at the point of release or removing them from the atmosphere. This includes carbon capture and storage (CCS), carbon capture and utilisation (CCU), and carbon dioxide removal (CDR).

Carbon Markets

Trading systems that allow the purchase and sale of credits, each typically representing one tonne of CO_2-equivalent avoided, reduced or removed. Compliance markets are regulated by governments and require entities to meet legally binding emissions caps or obligations. Voluntary carbon markets allow companies or individuals to buy credits to meet self-imposed climate targets or demonstrate climate leadership.

Carbon Dioxide Removal (CDR)

Human activities that remove CO_2 from the atmosphere and store it durably. CDR approaches include nature-based methods such as afforestation and soil carbon sequestration, hybrid approaches such as enhanced rock weathering as well as engineered methods such as direct air capture. Natural CO_2 uptake is not considered CDR.

Co-Benefits

Positive effects that arise in addition to the primary goal of carbon removal. These may include environmental gains (e.g. enhanced biodiversity), social improvements (e.g. better public health outcomes), and economic advantages (e.g. stimulating local economies or fostering sustainable business models).

Hard-to-Abate Sectors

Economic sectors where emissions are particularly difficult to eliminate due to locked-in technical, economic, or social constraints. These typically include heavy industry, aviation, agriculture, and shipping.

Legacy Emissions

Greenhouse gas emissions that have already accumulated in the atmosphere and continue to drive global warming.

MRV

MRV is an abbreviation for monitoring and/or measurement, reporting and verification. It describes a process to ensure that carbon dioxide removals are real, accurately measured, and transparently reported.

(Net-)Negative Emissions

The result of carbon removal processes that take more CO_2 out of the atmosphere than they emit, leading to a net reduction in atmospheric concentrations. As of current scientific understanding, net-negative CO_2 emissions could reduce global warming at a similar rate to how ongoing emissions increase it[17].

Net-Zero

A state in which greenhouse gas emissions released into the atmosphere are balanced by an equivalent amount of emissions removed, resulting in no net increase in atmospheric greenhouse gas concentrations which would stop global warming. Net-zero is used as a target by 2050 in order to limit global warming to 1.5 °C.

Overshoot

A climate scenario in which emission trajectories exceed temporarily cross the 1.5 °C threshold before later being brought back down. This requires substantial CDR to reduce temperatures after the overshoot has occurred.

Permanence

The duration that CO_2 can be safely stored and kept out the atmosphere. The duration varies depending on where and how CO_2 is stored. For example, injecting CO_2 into geological foundations can keep it stored for thousands of years, while storing it in biomass such as forests is more limited and prone to reversal due to wildfires and land degradation.

Residual Emissions

Emissions that are expected to remain in a net-zero future. These are emissions that, for technical, economic, or social reasons, are not fully eliminated.

Link to bibliography

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[17] Reisinger 2025