Chapter 1

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Mangrove replanting, Solomon Islands. By Wade Fairley

Chapter 1 | Introduction

Carbon dioxide removal (CDR) will be necessary to limit climate change, accompanying rapid and deep emissions reductions. This report builds on the previous two editions to track CDR development. It highlights new insights, explores knowledge gaps and defines core concepts while also aiming to improve the reliability and accessibility of CDR data.

Climate change is mainly driven by emissions of carbon dioxide (CO_2) to the atmosphere. These emissions come from human activities such as fossil fuel burning, land-use changes and industrial processes. Emissions of other greenhouse gases (GHGs), such as methane and nitrous oxide, are further exacerbating climate change. Whereas emission reduction seeks to limit the amount of CO_2 newly released to the atmosphere, CDR involves taking previously emitted CO_2 out of the atmosphere.

Meeting the Paris temperature goal – to limit global temperature rise to well below 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C – primarily requires rapid, deep and widespread reductions in emissions. CO_2 emissions have an enduring effect on the climate, causing global temperature to rise and stay elevated for millennia. Halting the rise in global temperature will therefore require bringing emissions of CO_2 all the way down to net zero. Reducing global temperature levels after a peak – for example, to return to 1.5°C after an overshoot period – would require net negative emissions, where global CO_2 removals exceed global CO_2 emissions.

The State of CDR 3rd Edition collates the latest information on the development of CDR. This first chapter sets out the role of CDR in climate change mitigation, defines CDR for the purposes of this report, outlines the characteristics of key CDR methods and presents an overview of the report and key improvements from previous editions.

1.1 Why CDR?

CDR is needed alongside deep and rapid emissions reductions to meet the Paris temperature goal. It should play a smaller role than emissions reductions given uncertainty around the feasible levels of scaling, sustainability limits, storage availability and the risk of reversal, among other constraints. In general, CDR should be seen as a limited resource that will need to be used prudently.

As highlighted in the IPCC's Sixth Assessment Report, CDR can fulfil three major functions.[1-3]

1. In the near term, CDR can help reduce net emissions.
2. In the medium term, CDR can counterbalance residual emissions to achieve net-zero CO_2 or net-zero GHG emissions.
3. In the longer term, CDR can help achieve net-negative emissions – if removals exceed emissions.

Role of CDR in mitigation strategies

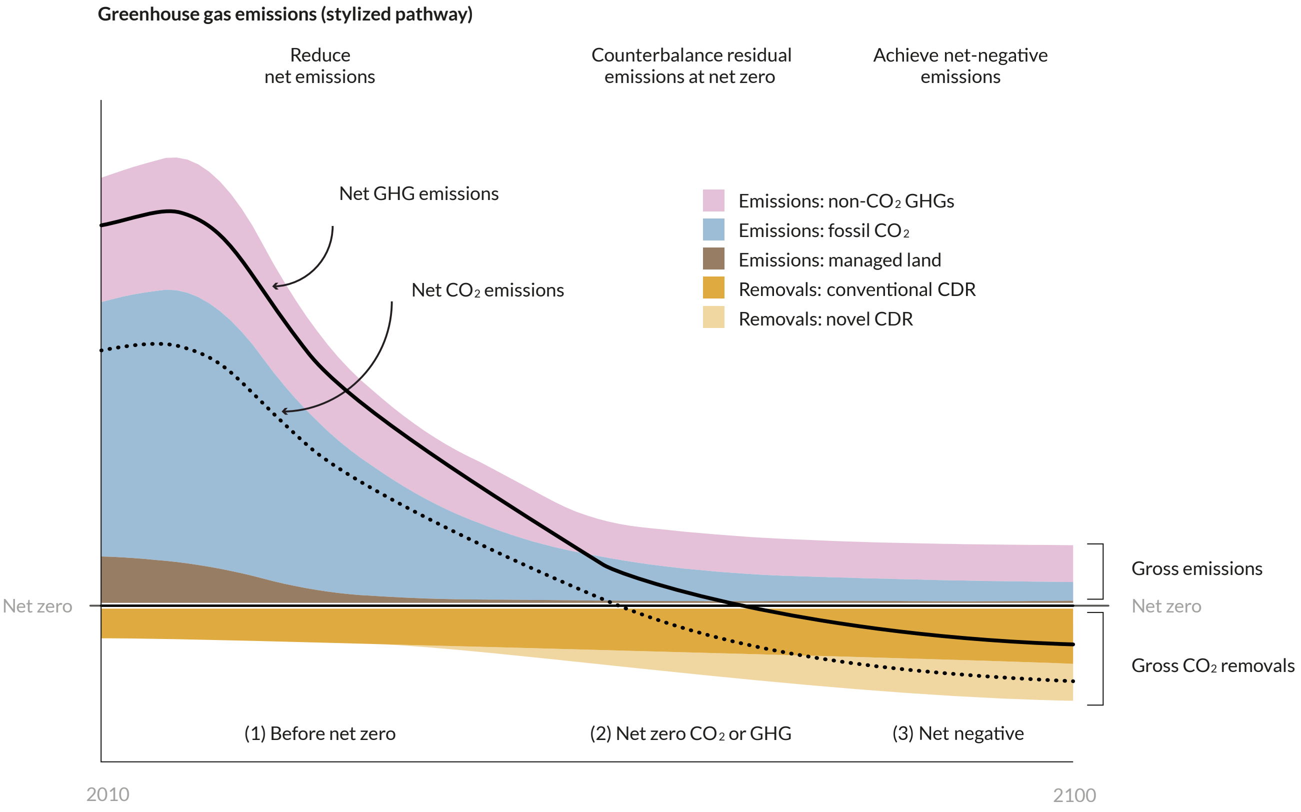


Figure 1.1 *Roles of CDR in ambitious mitigation strategies, applicable at national and global levels. Shaded areas show basic emission and removal components of mitigation pathways, and lines show the corresponding trajectories for both net* CO_2 *and GHG emissions. (Adapted from Babiker et al., 2022.)*[4]

1.2 Definitions of CDR

This report builds on the definition of CDR used by the IPCC[5]: CDR refers to human activities capturing CO_2 from the atmosphere and storing it durably in geological, terrestrial or ocean reservoirs, or in products. This includes human enhancement of natural removal processes but excludes natural uptake not directly caused by anthropogenic activities.

This definition contains three key principles.

1. The captured CO_2 must come from the atmosphere, not from fossil sources.
2. The subsequent storage must be durable, such that CO_2 is not soon reintroduced to the atmosphere (see Box 1.3).
3. The removal must result from human intervention that is in addition to Earth's natural processes.

Applying the three principles of CDR

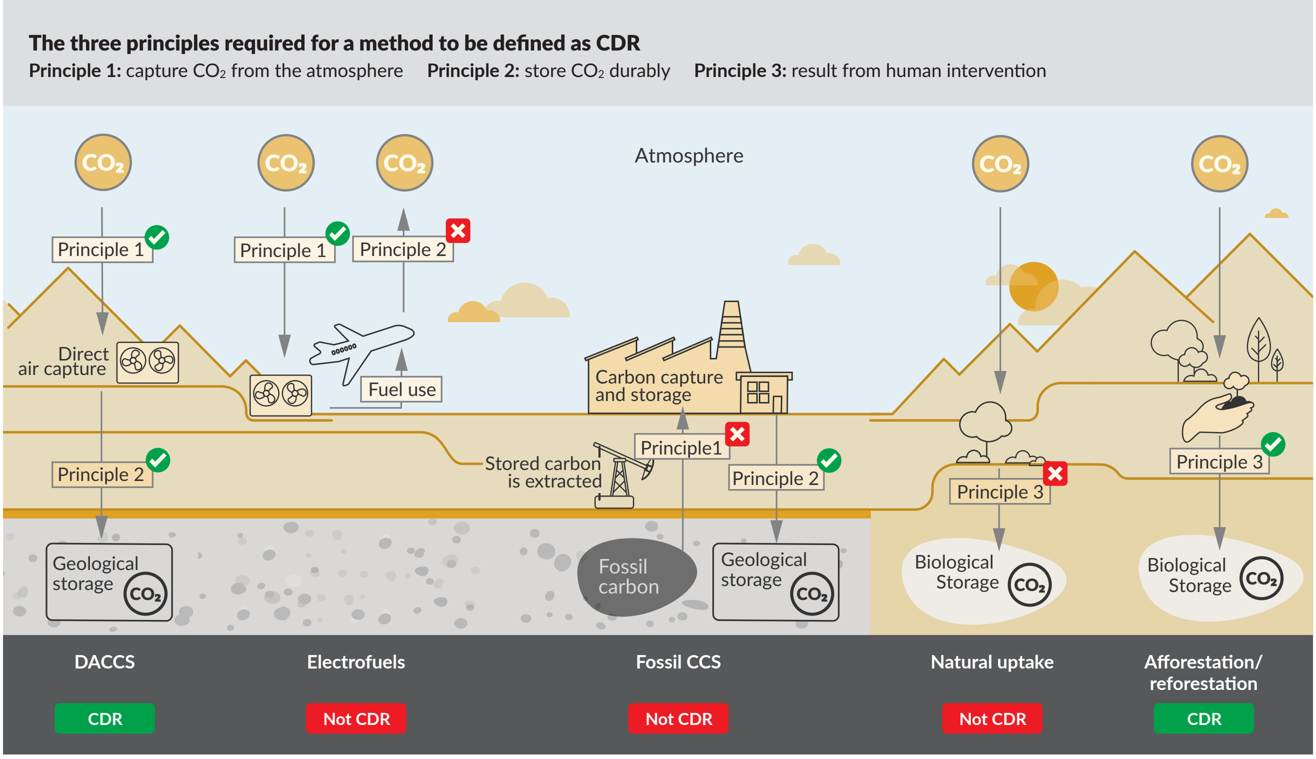


__Figure 1.2__ Examples applying the three principles of CDR to different processes. To be defined as CDR, a method must capture CO_2 from the atmosphere (Principle 1) and durably store it (Principle 2) as a result of human intervention (Principle 3). Direct air capture with geological storage (DACCS) satisfies all three principles and is CDR. Several related approaches do not satisfy at least one of the principles and hence are not CDR. For instance, direct air capture of CO_2 for use in short-lived products such as electrofuels does not meet Principle 2. Capture and geological storage from sources of fossil CO_2 does not meet Principle 1. Natural uptake of CO_2 via processes such as tree growth can meet Principles 1 and 2, but they only meet Principle 3 and count as CDR if enhanced through human activity such as afforestation/reforestation.

It is important to distinguish CDR from other related carbon management terms and concepts, such as carbon capture and utilization (CCU) and carbon capture and storage (CCS). CCU and CCS share components with some methods of CDR, but they do not necessarily result in durable removal of CO_2 from the atmosphere (see Box 1.1).

Box 1.1 Differentiating between CCS, CCU and CDR

CCS is a set of industrial methods for the capture of CO_2, the concentration of this CO_2 into a pure stream and its subsequent geological storage. When the CO_2 comes directly from fossil fuels or minerals (e.g. limestone), this process is an emission reduction rather than CDR. In climate policy and research, the term CCS is sometimes used only for the capture and storage of fossil CO_2 from point sources like coal power plants or cement clinker production. CCS can, however, be applied to CO_2 streams from ambient air, from seawater or the combustion of biomass; in each of these cases, the overall process meets the definition of CDR. This report refers to the first form of CCS as fossil CCS to distinguish it from the usage of CCS in the process chains of some CDR methods, such as direct air carbon capture and storage (DACCS) and bioenergy with carbon capture and storage (BECCS).

CCU is a set of industrial methods for the capture of CO_2 and its conversion into products. Again, CCU methods often use CO_2 from fossil sources, which is not CDR. If the CO_2 comes from the atmosphere and the product is durable (e.g. concrete aggregates and timber for construction), then these CCU applications also meet the definition of CDR. But many CCU products – such as carbonated drinks or fuels – are not durable (and thus not CDR) because they only store carbon for a matter of days or months before it is released back into the atmosphere.

Reporting and accounting perspectives for CDR

The wide-ranging GHG emission and removal effects arising from CDR activities call for robust measurement, reporting and verification (MRV). Policymakers, investors, market operators and the broader public seek trust in the efficacy of CDR methods and the veracity of reporting and accounting activities. Yet, CDR is measured and reported differently in different contexts, which can lead to ambiguity, confusion and inconsistent accounting in assessing progress for CDR within climate targets and strategies. Differences across two key perspectives – national GHG inventories and project-based assessments – reflect differences in objectives, system boundaries and temporal scope (see Table 1.1).

CDR in national inventories

National inventories record emissions and removals from activities within territorial limits during a regular (usually annual) reporting period. Emissions and removals are allocated to the sector in which they occur directly: energy, industry, land use or waste. As an example, removals from reforestation are reported in the land-use sector, while emissions associated with using vehicles to plant and manage the trees are reported separately in the energy sector. If the forest then burns down or is harvested in a later year, the emissions are reported in the inventory for that later year. Since national inventories for the land-use sector are typically based on direct observations, which do not separate natural CO_2 uptake, land-based CDR cannot be fully distinguished in these inventories (see Chapter 7). National inventories do not include emissions that occur in other countries, even if they are associated with imported or exported goods and services (although all emissions and removals are counted, and not double-counted, provided all national inventories are complete). Emissions associated with international shipping and aviation are reported separately. Durability and permanence requirements are not relevant to national inventories because any future reversal of a removal will be reported as an emission in the year it occurs. A nation's climate policy performance can be assessed according to temporal trends in the inventory and comparison to a historical base year. This approach is typically adopted, including in this report, when quantifying national pledges to reduce emissions and scale CDR (see Chapter 9).

CDR in project-based assessments

Project-based measurement seeks to address the question: what is the overall greenhouse gas (GHG) balance of a given project, including upstream and downstream emissions? The approach examines the GHG sources and sinks relevant to a complete CDR activity that, through its various system inputs and outputs, can span sectoral, national and temporal boundaries. In the reforestation example above, the emissions from the vehicles used in planting and management, plus other inputs such as fertilizer, would all be subtracted from the removals generated by the tree growth. This is the approach generally adopted for quantifying CDR credits in voluntary markets (see Chapter 4). While this provides a more complete picture of the climate impact of a project, it may lead to double counting across projects. For instance, emissions reductions from the use of more efficient vehicles could be counted by both the reforestation project and the vehicle manufacturer. Furthermore, there is some degree of choice in setting project boundaries, and assessments can be highly sensitive to this choice. A further sensitivity can come from choosing whether to estimate the absolute balance of GHGs attributable to the project or the GHG balance relative to a counterfactual scenario in which the project does not occur (known as a consequential assessment). Unlike inventories, project-based measurements usually consider permanence or durability, to address requirements from carbon crediting schemes regarding the period for which carbon must be stored and the management of reversal risk.

CDR in mitigation strategies

Quantified scenarios are increasingly used by parties to the UNFCCC, companies, and cities to establish pathways to achieve stated climate pledges, set benchmarks, and identify robust mitigation strategies. While inventory approaches focus on annual fluxes – either positive or negative – and project-based approaches focus on emissions and removals across the lifecycle of a given project, these pathways assess the contribution of a given removal activity to an intended overall climate change mitigation strategy. This is consistent with assessments of the role of CDR in future mitigation trajectories, in which a given activity is included as CDR if it is intended to remove carbon from the atmosphere as opposed to utilizing carbon as part of a broader carbon management strategy (see Box 1.1). This approach excludes, for example, the CO_2 removal that occurs passively as cement recarbonates over the lifetime of a built structure but would include active injection of atmospheric CO_2 to enhance the recarbonation process. It also likely rules out DACCS or BECCS where the captured CO_2 is used for enhanced oil recovery (EOR) due to uncertainties around net positive or negative emission outcomes (see Box 1.2). Policy documents, such as nationally determined contributions (NDCs), increasingly reflect these strategies by making explicit the role of CDR and the specific approaches that will be used to achieve climate targets.

Three approaches to CDR accounting and reporting

	Objective and governance context	System boundaries	Temporal scope
National inventories	To report total GHG emissions and removals categorized by sectors of activity in a given period	Emissions and removals occurring within national borders, allocated to the sector in which they occur directly	Emissions and removals reported as a time series (usually annual)
Project-based assessments	To measure the overall GHG balance of a complete project	Emissions and removals pertaining to the project lifecycle, across sectors and national borders	Emissions and removals integrated over the project's entire lifecycle
Mitigation strategies	To plan for CDR activities as part of a portfolio of measures to meet an emissions target or climate objective	Emissions and removals as part of a mitigation strategy (system boundaries generally wider than inventories but narrower than lifecycle assessments)	Emissions and removals integrated over the whole span of the planned activity for each method

Table 1.1

Gaps and grey areas

Several barriers impede the ability to make connections across CDR perspectives. The way in which some emissions and removals are measured and reported can differ greatly between the project level and the national inventory level. Project-level carbon credits are also being issued for CDR methods that currently lack approved inventory guidance, hampering the capacity of countries to report and account for them. This is particularly the case for several novel CDR methods including enhanced weathering (EW) and mineral products. The IPCC Task Force on National Greenhouse Gas Inventories has been tasked to provide a methodology report on CDR, CCS and CCU by the end of 2027. This is expected to lead to additional guidance on how to report removals for methods in national GHG inventories under the United Nations Framework Convention on Climate Change (UNFCCC).

Despite the obstacles, efficient scaling of CDR will involve MRV activities connecting and interacting at the project, national and organizational levels. Policies and measures designed by countries to incentivize CDR projects will be effective if, in turn, they create measurable signals in the national GHG inventory that allow such interventions to count towards national and international targets. Similarly, voluntary investments in CDR projects have greater legitimacy if the measured emissions and removals follow accepted international MRV standards and support alignment with national GHG inventories. Work is ongoing to address at least some of these gaps, although others face more significant challenges, such as improving the accuracy and spatial resolution of land monitoring methods.

Box 1.2 CDR grey areas

Depending on which approach is taken and how the IPCC's CDR definition is interpreted (e.g. what constitutes human activity), what counts as CDR can be contested. Not surprisingly for an emerging field, "grey areas" exist where delineations are not straightforward. Examples relevant for this report include the use of CO_2 from the atmosphere for EOR, the status of cement recarbonation and removals on abandoned agricultural land (see Chapter 7).

EOR with CO_2 from BECCS or DACCS. In this approach, non-fossil CO_2 is captured and injected into depleted oil reservoirs to increase oil recovery. Carbon that is captured and stored through this approach would be reported in a national inventory as removal, and the carbon released to the atmosphere from later combustion of the oil would be counted as an emission (where and when it occurs). A project-based accounting perspective would estimate the net effect of removals and emissions, which current estimates suggest would most likely lead to net emissions.[6] It is therefore ambiguous and case-specific whether EOR with non-fossil CO_2 could be considered an approach to either reduce emissions (similar to CCU approaches) or actively remove carbon from the atmosphere. Because of this, we choose not to include it in our estimates of CDR. BECCS and DACCS with EOR may still play a role in supporting innovation in the underlying technologies for future deployment in contexts that would count as CDR (i.e. without EOR).

Cement recarbonation. Cement production contributed around 4% of global emissions in 2023, primarily from limestone calcination. Over a building's lifetime, a proportion of the emitted CO_2 is reabsorbed via cement carbonation. We consider cement recarbonation not to be a direct human intervention but instead an indirect effect that depends on local climate conditions. Consequently, it is not included in our summary estimates of CDR – although it is a sink that contributes to counterbalancing human emissions. Furthermore, we do include approaches that directly enhance recarbonation as CDR in the "mineral products" category.

Abandoned agricultural land. We include forest regrowth on abandoned agricultural land in our summary estimates of CDR, despite debate over whether it constitutes direct human intervention. In some cases, land that was used for agriculture may be returned to forest through active tree planting, which is clearly CDR. In many cases, however, the forest cover may regrow without any direct human intervention, and agriculture is often abandoned for reasons other than CDR. This abandonment is less clearly a human activity, but even in these cases it could be argued that the continued non-use of the land reflects a human decision. Given this argument and a lack of data to distinguish between the different drivers and interventions in each case, we include all forest growth on abandoned agricultural land in the "afforestation, reforestation and forest management" category.

1.3 CDR methods and their characteristics

There are many CDR methods, covering a variety of ways to capture and store CO_2. Each CDR method can be thought of as a particular route through the Earth's carbon cycle – capturing carbon from the atmosphere and transferring it to durable carbon pools. Each of these pools is characterized by a different carbon storage timescale. CDR methods also differ in their readiness for scaling and their biophysical or technical sequestration potential (see Figure 1.3).

Routes through the carbon cycle

CDR methods use a range of capture processes and storage pools. Between capture and ultimate storage, carbon may be converted and transferred through a number of these carbon pools. Some methods involve transfers of carbon through multiple steps – and potentially over multiple years – while others combine capture and storage in a single step.

CO_2 sinks

Processes that capture CO_2 from the atmosphere are referred to as sinks.

Biological capture. Through the process of photosynthesis, CO_2 is taken up from the atmosphere and converted into biomass. On land, this capture occurs in vegetation including trees and agricultural crops. It also occurs in aquatic habitats, such as mangrove or kelp forests and seagrass meadows.

Chemical capture. A range of non-biological natural and industrial chemical processes can also capture CO_2. Some of these processes already occur as part of the Earth's natural carbon cycle. Through weathering, for example, certain minerals react with atmospheric CO_2 to produce either solid carbonate minerals or, in the ocean, dissolved bicarbonate. Other processes involve chemicals from human industrial activity. These can be alkaline wastes – for instance, from cement and steel production – or solvents and sorbents designed specifically to capture CO_2 and then rerelease it as a concentrated stream for use or storage.

Carbon pools

Vegetation, soils and sediments. Carbon can be stored in several ways on land. Although non-woody vegetation typically does not sequester the carbon captured in its biomass for long, individual trees can retain the carbon they capture for many decades, and forest ecosystems can retain carbon for centuries. Soils and sediments contain carbon in several forms, including organic carbon compounds from the residues of vegetation, animals and microbes, and inorganic carbon from weathered rocks. Human interventions can enhance the amount and durability of carbon on land, such as when biochar is applied to soils.

Marine inorganic and organic carbon. In the ocean, carbon is stored primarily as bicarbonate and carbonate ions, the dominant forms of dissolved inorganic carbon. The ocean also stores carbon in organic matter, including in sediments on the floor of the deep ocean that can sequester carbon on long timescales. Organic carbon is deposited onto these sediments as the remains of plants and animals that sink to the seabed.

Geological formations. Concentrated CO_2 streams generated from chemical capture can be injected into formations such as depleted oil and gas fields, saline aquifers or reactive mineral deposits underground. Various processes then act to sequester the CO_2 in these formations, including physical trapping by impermeable rocks, dissolving of the CO_2 in water and eventual mineralization.

Minerals. Solid carbonate minerals such as calcite ($CaCO_3$) are generated directly by some processes of geochemical capture, such as weathering or reaction with alkaline materials.

Built environment. Several products used in the construction of the built environment are durable stores of carbon. For example, timber has been used widely as a construction material for centuries and contains the carbon captured from the atmosphere by trees. Solid carbonate minerals generated through capture of CO_2 from the atmosphere can be used in products such as aggregates, asphalt, cement and concrete.

Durability

In this report, CDR methods are defined as sufficiently durable if the carbon pool has a characteristic storage timescale on the order of decades or more. However, this approach to what counts as CDR is not definitive. Policymakers and scientists have yet to agree on a clear definition of durable carbon storage (see Box 1.3), and expert interpretations are expected to evolve as research continues.

Different carbon pools have very different characteristic timescales for carbon storage and different risks of reversal (i.e. of rereleasing the carbon). Well-chosen geological and mineral formations offer the longest and least reversible storage. However, many other storage methods are widely regarded as valid for CDR, such as storage in trees and soils.

Box 1.3 Defining durable storage

The temperature-raising effect of fossil CO_2 emissions lasts for millennia[7] – an important consideration in any effort to balance emissions and removals. Any storage for shorter than this very long timescale will not fully counteract warming due to fossil CO_2 emissions. Maintaining net-zero CO_2 emissions – and hence halting global temperature rise – requires any residual emissions of fossil carbon to be balanced by capturing carbon from the atmosphere and storing it on the same millennial timescale.[8]

Some scientists argue that efforts to neutralize remaining fossil CO_2 emissions with CDR methods that have durabilities lower than 1,000 years are insufficient.[8,9] Storage in geological formations and through mineralization have the longest characteristic timescales. They are also the least susceptible to releasing CO_2 into the atmosphere as a result of human and natural disturbances once storage has occurred. Storage in geologic formations does carry risk of release – particularly during injection. However, in terms of like-for-like durability, it offers the closest equivalence to emissions of fossil CO_2 if selected and operated well.

Other scientists argue that there are sustainability and climate benefits to pursuing a portfolio of removal approaches with different durabilities.[8,10,11] Shorter-term storage can have value in meeting net emissions reduction targets, and counterbalancing biological CO_2 or methane emissions might also imply different durability requirements.[12] It is widely agreed that CDR does not encompass products that rerelease carbon within a year (e.g. direct air capture to fuels, or biomass to food). But there is currently neither a clear scientific basis nor a consensus among policymakers for incorporating a storage durability threshold in the definition of CDR.

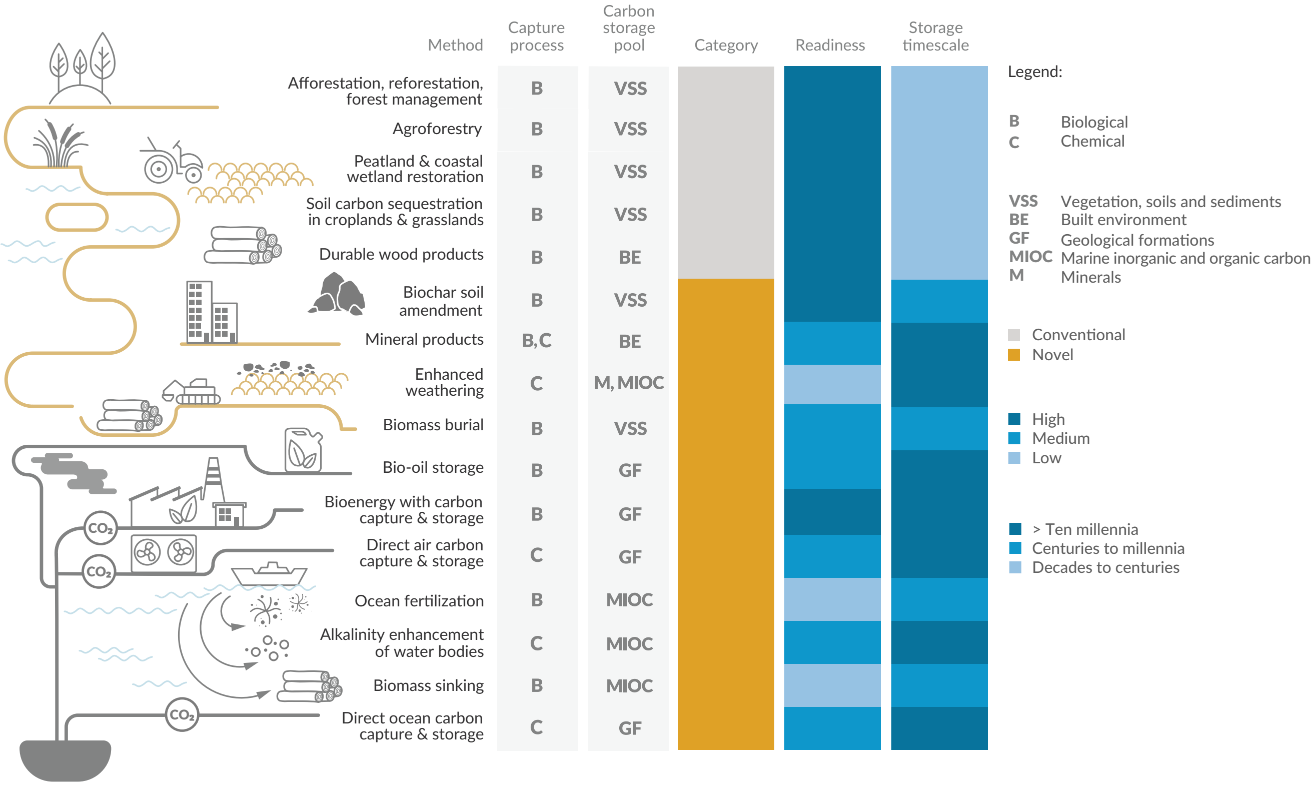
Existing policies by governments and voluntary standard setters have various minimum thresholds regarding storage.[13] Of 27 standards with an identified duration, over half require between 10 and 50 years, yet the single most common threshold – held by nine standards – is 100 years.[14] The EU's Carbon Removals and Carbon Farming Regulation (CRCF) has defined the concept of "permanent carbon removal" as storage for "several centuries", and a similar threshold of 200 years is a condition for the integration of CDR credits into the UK Emissions Trading Scheme (UK ETS).

The State of CDR assessments define durability based on the characteristic storage timescale of the relevant carbon pool. A method is counted as CDR if this timescale is on the order of decades or more. Figure 1.3 shows the characteristic storage timescales for different CDR methods. But the actual duration of storage depends not only on the general characteristics of the pool but also on human factors. For example, storage in soils could be reversed by a change in land use or extended through careful maintenance.

Categorizing CDR methods

The variety of processes for capturing and converting CO_2, and of options for its storage, means there are many potential methods of CDR. Figure 1.3 provides an overview of the key CDR methods considered in this report. While not exhaustive, this list is composed largely of methods that are already being deployed and those already analysed in the research literature. This report broadly follows the categorization and naming of methods used in the most recent IPCC assessment.[4] Whenever a specific CDR method is referred to in this report, the associated definitions and characteristics shown in Figure 1.3 apply. More detailed descriptions of these CDR methods can be found in the Glossary.

Characteristics of CDR methods



Method	Capture process	Carbon storage pool	Category	Readiness	Storage timescale
Afforestation, reforestation, forest management	B	VSS	⬜	■	□
Agroforestry	B	VSS	⬜	■	□
Peatland & coastal wetland restoration	B	VSS	⬜	■	□
Soil carbon sequestration in croplands & grasslands	B	VSS	⬜	■	□
Durable wood products	B	BE	⬜	■	□
Biochar soil amendment	B	VSS	🟧	■	▣
Mineral products	B,C	BE	🟧	▣	■
Enhanced weathering	C	M, MIOC	🟧	□	■
Biomass burial	B	VSS	🟧	▣	▣
Bio-oil storage	B	GF	🟧	▣	■
Bioenergy with carbon capture & storage	B	GF	🟧	■	■
Direct air carbon capture & storage	C	GF	🟧	▣	■
Ocean fertilization	B	MIOC	🟧	□	▣
Alkalinity enhancement of water bodies	C	MIOC	🟧	▣	■
Biomass sinking	B	MIOC	🟧	□	▣
Direct ocean carbon capture & storage	C	GF	🟧	▣	■

Legend:

B	Biological
C	Chemical
VSS	Vegetation, soils and sediments
BE	Built environment
GF	Geological formations
MIOC	Marine inorganic and organic carbon
M	Minerals
⬜	Conventional
🟧	Novel
■	High
▣	Medium
□	Low
■	> Ten millennia
▣	Centuries to millennia
□	Decades to centuries

Figure 1.3 *Summary of CDR methods, noting their respective capture process and storage carbon pool, categorizations as "conventional" or "novel", readiness, and characteristic storage timescale. Mineral products here include aggregates, asphalt, cement and concrete as well as biogenic CO_2 from BECCS or biochar applied in building materials. (Based on Babiker et al. 2022, Bustamante et al. 2023, and Cobo et al. 2023; see Chapter 10 for further discussion on readiness of different CDR methods.)*[4,15,16]

In policy debates and the media, CDR methods are often grouped into categories for ease of reference. A distinction is commonly made between "natural" or "nature-based" methods and "technological" or "engineered" methods. This categorization is contested, however, as well as blurred (a third "hybrid" category is also frequently employed). There are a variety of ways in which CDR methods could be grouped, and there is as yet no universal agreement on classification. The rows in Figure 1.3 indicate characteristics that are useful to consider when categorizing CDR methods in different contexts, including in different parts of this report.

This report refers to individual methods where possible, or groups them by common measurable properties where necessary. As in the 2nd Edition, this assessment also continues to distinguish between two broad categories: conventional CDR and novel CDR. This categorization is based on a combination of two of the methods' characteristics: their current level of readiness for deployment and the characteristic timescale of the carbon storage they employ.

Conventional CDR. This category encompasses CDR methods that are well established, already deployed at scale and widely reported by countries as part of LULUFC activities. The methods included in this group are afforestation, reforestation and forest management; agroforestry; soil carbon sequestration in croplands and grasslands; peatland and coastal wetland restoration; and durable wood products.

Novel CDR. This category encompasses all other CDR methods. These methods generally have a longer characteristic storage timescale and lower level of readiness for deployment and, as a consequence, are currently deployed at smaller scales (see Chapter 7). Examples of such methods include BECCS, DACCS, biochar soil amendment, mineral products, biomass burial, direct ocean carbon capture and storage (DOCCS), and alkalinity enhancement of water bodies.

1.4 Purpose and scope of this report

Interest in CDR as a necessary component of climate action continues to intensify among policymakers, investors, researchers and non-profit organizations. Experience with – and information about – CDR also continues to grow, including research and development, demonstration projects, purchases of removal credits, and recommendations for best practices from public and private sector organizations. CDR requires strong policies and governance to support the development and deployment of a diverse range of methods and ensure that projects are implemented responsibly. However, recent analysis (published in our first *Insight Report*) reveals that transparency around CDR commitments in national climate pledges remains limited, with only a handful of countries providing clear information on their intention to scale CDR.

While a scale-up of CDR will be needed to address future climate change, the appropriate level of CDR deployment remains uncertain. This report estimates future CDR needs based on the best available science, but there are significant uncertainties in both future emissions and the climate response to emissions and removals. It is also uncertain how effective CDR approaches will be in a changing climate. We may need far more CDR than currently envisioned to reach temperature stabilization or reverse warming after surpassing 1.5°C. This underscores the potential need to build capacity for large-scale deployment – and the value of deploying CDR proactively now as a hedge against future climate uncertainties. This deployment will involve concerted effort across many dimensions, and tracking this effort requires a resource for reliable, transparent and up-to-date data.

The State of CDR aims to meet this need. The 1st Edition, released in January 2023, provided a comprehensive global assessment of developments in CDR. The aim of the report was to inform and guide the further development of CDR by providing a clear, independent and authoritative assessment of available data. The 2nd Edition, released in 2024, expanded the scope and depth of the assessment. It introduced a model based on theories of innovation to provide a more coherent picture of CDR development, tracking the progression from research and development through demonstration, upscaling and market growth. The 2nd Edition also broadened coverage by introducing new chapters on demonstration and upscaling, the voluntary carbon market, and MRV. It expanded the author team and improved methodologies for estimating current CDR levels and assessing future requirements.

Interest in CDR continues to accelerate. The response to the first two editions highlighted the demand for regular tracking of the rapidly evolving CDR landscape. This 3rd Edition continues and expands the assessment of CDR development. In the next three chapters, the report assesses the state of CDR in terms of research and development (Chapter 2), demonstration and upscaling (Chapter 3) and voluntary demand for CDR (Chapter 4). It then examines enacted policy approaches and commitments by governments to develop CDR (Chapter 5) and reviews how communication and public perceptions are evolving (Chapter 6). The report's final chapters look at the amount of CDR currently being deployed (Chapter 7), the amount required by pathways that meet the Paris temperature goal (Chapter 8), and the gap between government proposals and pathways to the Paris goal (Chapter 9). A new chapter assesses current evidence on the costs and potentials of CDR methods (Chapter 10).

Beyond the new chapter on costs and potentials, the 3rd Edition introduces several key advances and benefits from new analyses and data collection efforts. These include a survey on the pipeline of CDR projects and future company ambitions, and new integrated assessment model scenarios submitted by modelling teams for global and national models. This edition also includes an expanded set of indicators and a revised data portal, freely available via https://www.stateofcdr.org/data-portal/3rd-edition. Despite these enhancements, important gaps remain. Most importantly, increased data transparency and dedicated data gathering efforts focused on activities outside Europe and North America are needed to provide a fuller picture of the state of CDR.

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