Position paper

Carbon Capture (Utilisation) and Storage and Carbon Dioxide Removal

The Background

The Paris Agreement (PA) aims to limit global warming to well below 2 °C and preferably to 1.5 °C above preindustrial levels. However, we are currently heading towards global warming of 2.5 °C or more unless far-reaching, rapid and systemic transformations take place in all sectors and on a large scale. In order to reach net-zero and net-negative emissions, both deep cuts in greenhouse gas (GHG) emissions and the deliberate removal of CO_2 from the atmosphere are required. All projected pathways of the Intergovernmental Panel on Climate Change (IPCC) that limit global warming to 1.5 °C include (amongst other measures) the anthropogenic removal of CO_2 from the atmosphere (carbon dioxide removal, CDR) and the capture and storage of fossil CO_2 from industrial processes (carbon capture (utilisation) and storage, CC(U)S).[1] Negative emissions as a result of CDR will be required even if most industrial sectors achieve deep decarbonisation as there will always be some hard-to-abate residual GHG emissions, for example nitrous oxide and methane emissions from agriculture. These hard-to-abate residual emissions are estimated to amount to at least 100 Gt CO_2 globally up to 2100.[2] Moreover, as GHG emissions are currently not decreasing fast enough, CDR is needed to contribute to global climate mitigation efforts even in the short term.

CC(U)S approaches reduce the amount of CO_2 that would otherwise be released into the atmosphere by capturing it at point sources (e.g. stack emissions) and then storing it in geological formations for long timescales (CCS) or in long-lived products (CCUS). These methods therefore contribute to mitigation efforts by reducing emissions.

The two most relevant sources of CO_2 in this context are: i) fossil fuels used in power generation and some industrial processes (e.g. coal, gas and oil); and ii) production processes emitting CO_2 that is not derived from fossil energy carriers (e.g. two thirds of CO_2 emissions in cement production come from chemical transformation). The implementation of CCS and CCUS currently faces technological, economic, institutional, environmental and socio-cultural barriers, and many technologies are still in their infancy.

In addition to the capture of fossil fuel-derived CO_2 from industrial point sources, the removal of CO_2 that is already in the atmosphere by deliberate human activities and its long-term storage in geological (terrestrial and marine) sinks or in products will be needed. This process will lead to negative emissions. The right side of Figure 1 shows CDR approaches that can be divided into three categories: technological, natural, and a combination of technological and natural (technological and combined approaches are often referred to as novel technologies). Some CDR approaches involve CCS methods for storing CO_2, for example bioenergy with CCS (BECCS) and direct air carbon capture and storage (DACCS); however, in contrast to conventional fossil CCS, these methods remove CO_2 from the atmosphere and therefore actively reduce its CO_2 concentration. Natural CDR methods remove CO_2 from the atmosphere by enhancing natural carbon sinks, for example via afforestation, the restoration of wetlands and mangroves or in agricultural systems.

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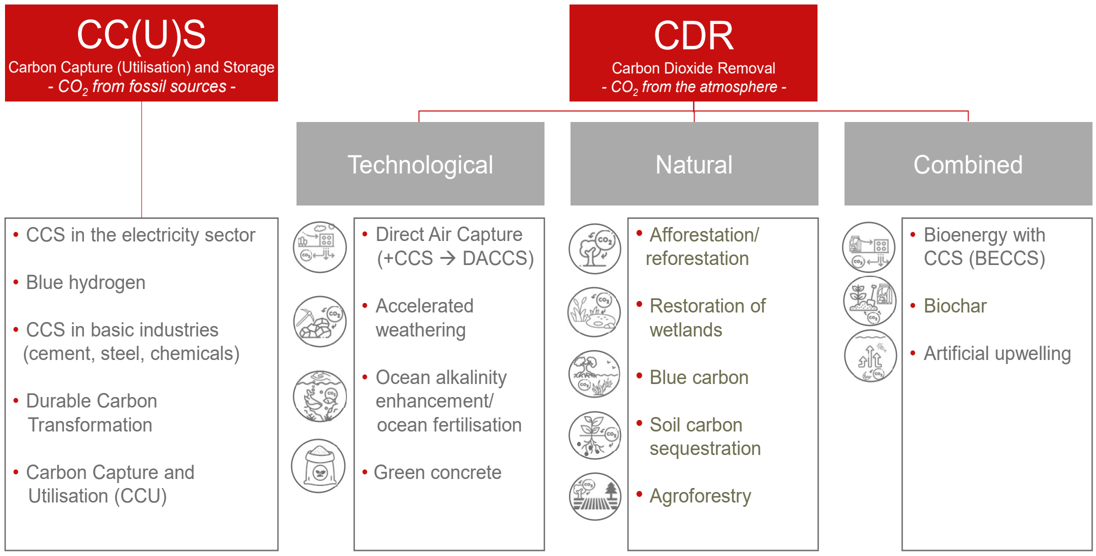

Figure 1: Summary of the main CC(U)S and CDR approaches and technologies

Market mechanisms agreed by the parties to the United Nations Framework Convention on Climate Change (UNFCCC) and set out in the Paris Agreement's Article 6 rulebook are currently under development. They will support the transfer of emissions reductions between countries and incentivise private sector investments in climate-friendly solutions. Their implementation is expected to support both CDR and CC(U)S approaches.

Against this background, the discussion on CC(U)S and negative emissions is moving up on the global climate policy agenda. Many countries have long-term net-zero pledges and targets, and achieving these targets requires the implementation of many different approaches, including CDR and CC(U)S on large scales. However, although there is widespread agreement that CDR and CC(U)S are essential for upscaling climate mitigation efforts, uncertainties remain about which combinations of methods should be deployed where, by whom, in what way, to what extent, by when and with what safeguards.

Our position and recommended actions

GIZ agrees that meeting the Paris Agreement's targets requires large-scale transformational action. We realise that deep cuts in GHG emissions alone are insufficient to reach net-zero emissions by 2050 and that negative emissions will also be needed. In our opinion, the decarbonisation of all sectors of our economies is not being rolled out fast enough, and feasible solutions are required for some hard-to-abate residual GHG emissions.

The partner countries of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH increasingly request support on both CDR and CC(U)S methods as relevant approaches for their transformation pathways. There is no 'one size fits all' approach that will suit all the partner countries' legal, social and economic conditions. In any case, GIZ is bound by the legal provisions in force in its partner countries as well as in Germany and the European Union at any point in time. All possible options for reducing emissions and removing CO_2 from the atmosphere will be evaluated against the following GIZ positions:

(1) GIZ position: All aspects necessary to ensure ecological, economic and social sustainability as well as relevant legal safeguards will be assessed before promoting any CDR or CC(U)S measures. Possible trade-offs of both CDR and CC(U)S measures with other environmental or societal targets will be dealt with transparently and in a participatory way. Life cycle assessments should be conducted to provide an understanding of the overall environmental impacts of different options. An analysis of potential lock-in effects, especially for cost-intensive technologies and infrastructure, should be part of the assessment. These considerations apply to all CDR and CC(U)S measures.

GIZ will not support any CC(U)S or CDR measures that have not been subjected to a comprehensive and holistic assessment, and it will consider the feasibility, costs and social and environmental impacts of different options on a case-by-case basis.

(2) GIZ position: Political and legal framework conditions and societal discussions relevant for the implementation of CC(U)S and CDR methods deter-

mine the enabling environment for the implementation and scope of potential activities.
Public acceptance is key to the introduction of any such technology. Public consultations, hearings and surveys are essential for ensuring public acceptance and social peace. This is particularly true for CC(U)S, while many natural CDR methods are widely accepted. However, both political and legal support and public acceptance are crucial for the more technical CDR approaches, especially those combined with CCS methods (e.g. BECCS).

GIZ will promote appropriate political and legal framework conditions and public acceptance in relevant partner countries and monitor further developments.

(3) GIZ position: Activities that are implemented for the purpose of generating carbon credits will be carefully analysed to avoid greenwashing.
Carbon credits can be issued for reduced or avoided CO_2 emissions and for carbon sequestration. This includes CC(U)S and CDR, and carbon credits could help scale up these methods. However, carbon credit schemes are increasingly criticised due to issues related to their methodologies and credibility and, ultimately, their ability to deliver meaningful climate action. This is particularly true for activities in the land sector (e.g. afforestation, landscape restoration, blue carbon or soil carbon sequestration), mainly due to concerns regarding the permanence of storage and the complexities involved in the monitoring and verification of nature-based carbon credits. The Paris Agreement's Article 6 framework is expected to set out rigorous and globally agreed upon rules for carbon crediting once it has been finalised. Activities that cannot create carbon credits acceptable under Article 6 should therefore not be promoted, not even for the voluntary market, in order to avoid criticism and allegations of greenwashing. Unintended negative impacts on other environmental and/or social issues must always be avoided. Ideally, projects that generate carbon credits should produce co-benefits beyond climate mitigation.

GIZ will evaluate potential activities involving carbon credits very carefully to ensure that carbon credits are of high quality and reflect true and verifiable mitigation outcomes, moreover activities that focus exclusively on the generation of carbon credits will be avoided.

(4) GIZ position: Both emissions reductions and CO_2 removals are required. CDR approaches should complement measures to reduce GHG emissions but must not be used as an excuse for less ambitious reduction efforts.
The implementation of CDR should not be used as an excuse to delay efforts to reduce emissions. Accounting systems for emissions reductions and negative emissions should remain separate to ensure transparency and accountability. Separate targets and monitoring and reporting systems should be established for reductions and removals.

GIZ will consider both negative emissions and emissions reductions when advising partner countries. Activities will be embedded in strategies that address both aspects simultaneously but separately. The implementation of CDR will never be used as an excuse for less ambitious reduction efforts.

(5) GIZ position: Some CDR approaches require further research and development before their large-scale application becomes feasible and possible.
More research is needed to fully understand the environmental impacts that some potential CDR approaches might have. Some methods might pose significant and unacceptable ecological risks, and the climate mitigation benefits of some approaches are still not well enough understood (e.g. introducing alkalinity-enhancing compounds into oceans or artificial upwelling which involves nutrients being brought from the deep ocean to the surface to stimulate the fixation of CO_2 by algae).

GIZ will only engage in the upscaling of technologies if their long-term feasibility and sustainability are well researched and tested, especially in the case of large-scale CDR measures in natural ecosystems.

(6) GIZ position: Potential trade-offs associated with CDR approaches will be carefully evaluated before action is taken.
The effective protection and conservation of existing carbon-rich ecosystems should take precedence over new land-based CDR projects. The implementation of CDR methods must not increase land-use competition and should aim to create co-benefits (e.g. increasing soil moisture, enhancing biodiversity or recovering wastelands). The introduction of new technologies (e.g. biochar production) for carbon sequestration must not lead to unintended negative impacts, such as the degradation of forests. There are many biological CDR approaches that are well known and widely implemented, for example increased carbon sequestration in agricultural soils,

afforestation and the rewetting of organic soils. These methods often also deliver co-benefits for other targets such as food security and biodiversity conservation. The main objectives of current GIZ projects involving CDR approaches are usually food security and rural or agricultural development rather than the removal of CO_2 from the atmosphere; however, GIZ will promote CDR more prominently within the scope of such projects.

GIZ already considers natural CDR approaches in its project implementation and will continue to promote them, providing that all necessary safeguards are addressed.

(7) GIZ position: CCS to abate emissions is controversial and will be carefully assessed.
The mitigation of CO_2 emissions in the energy sector should focus on renewable energy and energy efficiency. CCS for power plants is comparatively expensive (which could lead to economic lock-in effects) and requires substantial additional amounts of energy. Using CCS in the energy sector would unnecessarily extend the lifetime or the overall retention time of fossil-fuelled power plants in energy systems. This would likely slow down the transition towards a fully renewable and efficient energy system. In contrast, there are industrial processes (e.g. in the cement industry) where CCS represents a feasible solution for sequestering hard-to-abate CO_2 emissions.

GIZ will not support CCS for CO_2 from fossil fuels in the energy sector (e.g. power generation) to avoid the risk of extending the lifetime of non-renewable energy generation systems. In hard-to-abate sectors (e.g. cement, steel) GIZ supports CCS based on CO_2 from fossil fuels as long as the positions and recommendations outlined in this paper are considered.

(8) GIZ position: CCU solutions based on fossil CO_2 delay but do not reduce CO_2 emissions into the atmosphere while CCUS can lead to negative emissions if it is based on CO_2 sourced from the atmosphere.
CCU applications that use fossil fuel-derived CO_2 only delay the emission of this fossil CO_2 and do not eliminate it over longer time scales. They can, however, contribute to mitigation efforts if they replace conventional fossil CO_2-based products with products that source CO_2 from the atmosphere. Such products can be carbon neutral but do not represent negative emissions if the CO_2 in the products is released again after use at short time scales (e.g. e-fuels and biofuels). CCUS approaches can contribute to mitigation efforts if CO_2 is stored in products for a climate-relevant time horizon. If the CO_2 is sourced from the atmosphere, CCUS may even lead to negative emissions, e.g. in the production of carbon fibres and green concrete; however, large-scale application will require further research and development.

GIZ will only support CCU and CCUS activities that lead to real emissions reductions or that source CO_2 from the atmosphere.

(9) GIZ position: The storage of CO_2 in geological structures is associated with risks in terms of retention rates (permanence) and needs to be managed over long timescales.
Storage and disposal sites (e.g. geological formations such as sandstone or oceanic ridge basalt) must pose no risk of leakage, and retention rates must be close to 100 %. The storage of CO_2 in natural systems or geological structures should only be promoted if long-term management structures are established. Areas prone to seismic and/or volcanic activities in partner countries should be ruled out from storage approaches. Three-dimensional spatial planning measures must be in place at potential storage and disposal sites. Monitoring systems must also be in place to identify potential carbon leakages and for carbon stock taking, including instruments such as sensors and remote sensing applications. It must be ensured that knowledge about storage and disposal sites can be proliferated in mandated institutions in the long run.

GIZ will act as an honest broker but will not actively promote the development of geological storage sites.

Innovative technologies

In this chapter, we provide a selection of potential CDR approaches which we feel are important for GIZ's work. Several additional CC(U)S and CDR technologies are currently under discussion, but most of them are still under research and not yet ready for application. **Disclaimer:** *Not all technologies described are innovative; sometimes, it is the GIZ project implementation approach that enables innovation.*

Afforestation/reforestation and improved forest management
One well-established technology is the planting, restoration and sustainable management of forests which results in the sequestration and storage of carbon. These methods are already widely implemented. There are many potential co-benefits associated with them, such as an increase in biodiversity and recreation opportunities, soil improvement, slope stabilisation, enhanced employment, and the provision of agroforestry products, wood as a primary resource and non-timber forest products. The

carbon capture potential is limited and estimated at 0.5-10 Gt CO_2e a year. Extensive reforestation might create competition for land and raise legal issues. The restoration and improvement of existing forests will be prioritised over the establishment of new forested areas.

Rewetting and restoration of wetlands
Another important CDR measure is the rewetting and/or restoration of wetlands, such as peatlands, to enhance carbon storage. Although it is a cheap method, it is limited in scope and its potential, estimated at 1 Gt CO_2e a year, is relatively low. Co-benefits include the provision of habitats for biodiversity and the improved function of wetlands as buffer zones against floods following extreme weather events.

Blue carbon
Blue carbon is CO_2 that is captured and stored by coastal and marine ecosystems such as mangroves, salt marshes, tidal marshes, seaweed beds, kelp forests and seagrass meadows. These ecosystems sequester and store enormous quantities of CO_2 in both plants and sediments. Carbon removal in these ecosystems can be increased by restoring lost and degraded areas, improving the management of existing ecosystems or establishing new coastal habitats. There are various potential co-benefits for biodiversity, coastal resilience, erosion control, tourism, etc.

Soil carbon sequestration (carbon farming)
Land management changes that increase soil carbon contents include well-established CDR methods based on land use, land-use change and forestry (LULUCF). They include agroecological and pastoral techniques such as no-till soil preparation, crop rotation, the introduction of cover crops and improved livestock grazing management. There are no significant barriers to land management changes, and they are no-regret measures with a low land and water footprint. They are well researched, although most research and scientific discussion focuses on specific soil and climate conditions. They are knowledge- and cost-intensive and require knowledge transfer via extension systems in many GIZ partner countries. Modelling estimates suggest a potential to remove 1-11 Gt CO_2e a year globally.

BECCS
Bioenergy with carbon capture and storage combines the sequestration of carbon in biomass with the use of this biomass for energy generation coupled with CCS to capture and store the biogenic carbon geologically, thereby removing it from the atmosphere. If implemented well, BECCS can reduce air pollution, provide an energy resource, increase employment and enhance biodiversity. However, there is a risk of increasing competition for land, water and other resources if BECCS is based on bioenergy plants grown solely for this purpose, with possible negative consequences for biodiversity, ecosystem services, livelihoods and food systems. The method is cost-intensive and needs a strong business case. The carbon capture potential is estimated at 0.5-11 Gt CO_2e a year.

Biochar
Biochar results from the burning of biomass under low-oxygen conditions (pyrolysis). It is one of the best-researched CDR technologies, accounting for about 40 % of CDR research papers published since the early 1990s. There are multiple potential co-benefits related to waste management (recovery of carbon and nutrients) and agriculture (soil texture, water and nutrient adsorption associated with soil enhancers) although long-term research is still needed. Various articles calculate a sequestration potential of 0.7-1.8 Gt CO_2e a year.

Current and potential future collaboration partners

To deepen our knowledge and further engage with CC(U)S and CDR, it is recommended to maintain and establish new collaborations with key actors in this field. GIZ already has a strategic partnership with the **German Federal Environment Agency** (UBA) which published a position paper on CCS in 2023.
The **Mercator Research Institute on Global Commons and Climate Change** (MCC), founded by the **Potsdam Institute for Climate Impact Research** (PiK) which is a government-funded research institute addressing crucial scientific questions in the fields of global change, climate impacts and sustainable development and ranks among the top environmental think tanks worldwide, is one of GIZ's collaboration partners and recently published the report The State of Carbon Dioxide Removal. The objective of the **German Biomass Research Centre** (DBFZ) is to conduct applied research and development on the use of renewable biological resources to produce energy and materials in the bioeconomy, with particular attention to innovative technologies, economic impacts and environmental concerns. GIZ and the DBFZ have been collaboration partners since 2010.
The **Wuppertal Institute for Climate, Environment and Energy** has long-standing experience in CCS, with a focus on technology impact analysis and socio-economic framework conditions.

The **International Energy Agency** (IEA), established by leading industrial countries in the 1970s, is one of the most influential stakeholders in the global energy discourse. Its assessment reports and analyses are among the most highly respected publications in the energy sector. The **Thünen Institute** is a federal institution under public law and a higher federal authority within the German Federal Ministry of Food and Agriculture (BMEL). It conducts cross-disciplinary research to promote the sustainable development of rural areas, agriculture, forestry, timber and fishing, taking into account socio-economic, ecological and technological aspects. The German Federal Ministry of Education and Research (BMBF) funded the research missions **CDRmare and CDRterra** to look at sinks in decarbonisation pathways and CO_2 removal methods. GIZ is part of an expert advisory group for CDRmare.

Glossary[3]

- **Carbon capture and storage (CCS):** A process in which a relatively pure stream of CO_2 from industrial and energy-related sources is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the atmosphere. From a long-term point of view, such 'storage' is the final disposal of CO_2.
- **Carbon capture and utilisation (CCU) and carbon capture, utilisation and storage (CCUS): CCU is a** process in which CO_2 is captured and then used to produce a new product. If the CO_2 is stored in a product for a climate-relevant time horizon, this is referred to as carbon capture, utilisation and storage (**CCUS**). Only then, and only combined with CO_2 recently removed from the atmosphere, can CCUS lead to carbon dioxide removal.
- **Carbon dioxide removal (CDR):** Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial or ocean reservoirs or in long-lived products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air carbon capture and storage (DACCS) but excludes natural CO_2 uptake not directly caused by human activities.
- **Carbon sink:** A reservoir (natural or human, in soil, ocean and plants) where a GHG, an aerosol or a precursor of a GHG is stored.
- **Carbon sequestration:** The process of storing carbon in a carbon pool.
- **Mitigation (of climate change)/carbon reduction:** A human intervention to reduce emissions or enhance the sinks of GHGs.
- **Negative emissions:** Removal of GHGs from the atmosphere by deliberate human activities, i.e. in addition to the removal that would occur via natural carbon cycle processes.
- **Net negative emissions:** A situation of net negative emissions is achieved when, as a result of human activities, more GHGs are removed from the atmosphere than are emitted into it. Where multiple GHGs are involved, the quantification of negative emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential and others as well as the chosen time horizon).

References

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