Carbon Dioxide Removal

RESCUE

Climate Classroom

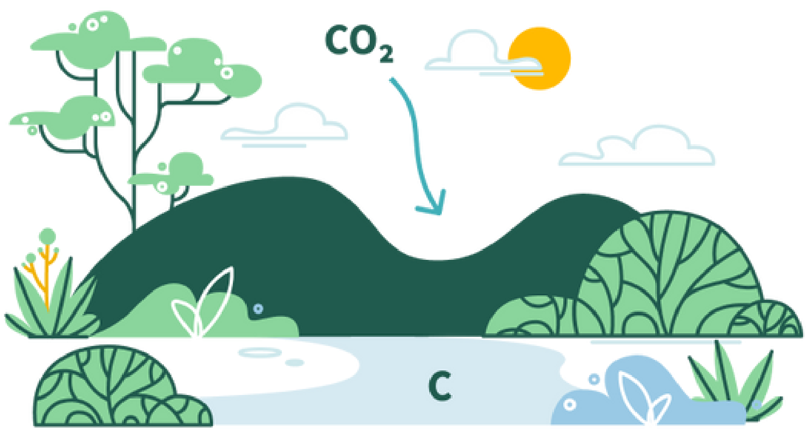
Stringent emission reductions are urgently needed to achieve the goals of the Paris Agreement. In addition, it is becoming increasingly clear that carbon dioxide removal (CDR) is necessary to complement these efforts.

Many research efforts are directed towards understanding the role that CDR can play in mitigating climate change and achieving a climate-neutral world in the second half of this century, as well as their potential impacts and risks. In this climate classroom, we delve into the basic concepts behind CDR.

Carbon dioxide removal (CDR) refers to any human-led techniques or strategies for removing carbon dioxide (CO_2) from the atmosphere and storing it for long periods of time.

Carbon dioxide (CO_2) plays a key role in regulating the Earth's temperature and sustaining life by acting as a greenhouse gas. However, human activities have significantly increased CO_2 levels in the atmosphere, causing global warming and endangering the stability of the Earth system.

To partially counteract this excess atmospheric CO_2, CDR methods can be used. There are several types of CDR techniques, each with distinct approaches to removing CO_2 from the atmosphere, as well as varying storage periods, economic costs and levels of technological development. They also have different co-benefits, adverse impacts, and risks.



Glossary

Paris Agreement

The Paris Agreement is a landmark international treaty aimed at combating climate change. It was adopted in December 2015 at the 21st UN Climate Change Conference (COP21) in Paris, France. It represents a legally binding commitment to tackle climate change by holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels.

Climate neutral

Climate neutral, understood as net-zero greenhouse emissions, refers to achieving a balance between the amount of greenhouse gases emitted into the atmosphere and the amount removed.

Funded by the European Union

CDR methods are mainly divided into two categories:

Nature-based

These methods enhance the natural processes of the carbon cycle, moving CO_2 from the atmosphere to other reservoirs, such as soil, vegetation or oceans. Nature-based CDR may offer additional benefits, such as promoting biodiversity, food security and protection against natural disasters, e.g. flooding.

However, land-based CDRs can compete for land use with other human activities, and ocean-based CDRs can have unintended remote impacts outside of the application area. In addition, their effectiveness for long-term storage of CO_2 can vary.

Technology-based

These alternatives are less well-known, and rely on the use of technology and energy to enable chemical processes that transform carbon into other compounds for storage, for instance, direct air carbon capture and storage (DACCS).

These methods usually entail few risks and can store carbon for long periods. Nevertheless, they are often energy-intensive and depends on the availability of storage sites.they can store carbon for longer periods.

Therefore, while CDR has the potential to assist climate change mitigation policies, unresolved questions about effectiveness and risks still remain. However, it is important to understand that there is no one-size-fits-all solution, and determining the optimal approach hinges on the unique context.

CDR in a climate change context

Achieving climate neutrality is essential to limit global warming and meet the goals of the Paris Agreement. However, it is recognised that climate change mitigation through emission reductions alone will not be sufficient (IPCC, 2023). Complementing stringent emission reductions with CDR is necessary to achieve net zero or negative emissions. This is especially important for addressing any carbon emissions that are difficult to reduce or eliminate from their source, also known as hard-to-abate emissions, which include the iron, steel and chemicals industries.

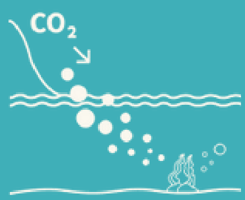
While CDR cannot replace the need for immediate and strong emission reductions, it is included in all climate scenarios that limit global warming to 1.5°C and 2°C or less by 2100, according to the IPCC (IPCC, 2023).

The European Commission has created a certification framework for carbon removal to encourage more efforts and prevent "greenwashing" by allowing companies to demonstrate their effectiveness in this field (European Commission, 2024). Recently, the Council and European Parlament reached a provisional political agreement on a regulation to establish this certification framework (European Council, 2024).

However, it is crucial to assess the effectiveness and potential environmental impacts of CDR options before implementing them on a large scale. To this end, the RESCUE project addresses these knowledge gaps by designing climate neutrality scenarios that include CDR portfolios, while assessing the efficiency, potential impacts and risks of implementing these technologies. This will provide key information to inform future climate policies and determine the most suitable CDR technologies to put into practice.

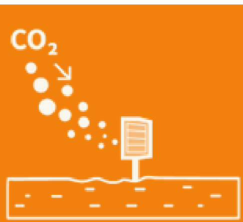
CDR in RESCUE

RESCUE investigates the potential of many land- and ocean-based CDR methods. However, only four of these are considered in the proposed climate neutrality scenarios that are simulated with climate computational models. These CDRs are described below:



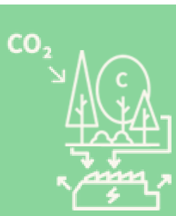
OCEAN ALKALINITY ENHANCEMENT (OAE)

The ocean is one of the most important natural carbon sinks. OAE involves the addition of substances like limestone to seawater to make it more alkaline, increasing the capability of the ocean to absorb CO_2. As a result, the ocean can store more carbon for a long time, helping to reduce the amount of CO_2 in the atmosphere. This is done through various methods, such as spreading alkaline substances in the open ocean, or depositing them on the coast.



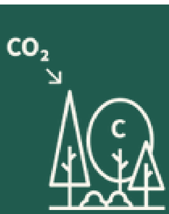
DIRECT AIR CARBON CAPTURE AND STORAGE (DACCS)

DACCS involves the removal of CO_2 from the air using big fans or similar devices that pull large amounts of air through chemicals or porous materials attached to solid structures, with a strong affinity for CO_2. This captured carbon then needs to be stored underground at specific geological sites (Gambhir and Tavoni, 2019).



BIOENERGY WITH CARBON CAPTURE AND STORAGE (BECCS)

Biomass is organic material from living things, like plants. When plants grow, they naturally absorb CO_2 from the air through photosynthesis, keeping it in their cells. Later, biomass can be burned to produce energy, releasing CO_2. With BECCS, CO_2 is captured and then stored in geological sinks (European Parliament, 2021).



AFFORESTATION / REFORESTATION (A/R)

Trees and plants absorb CO_2 through photosynthesis, producing oxigen and converting CO_2 it into organic carbon, which is stored in the vegetation and soil. Increasing forested land through afforestation (converting abandoned and degraded lands into forests) and reforestation (replanting trees in deforested lands) helps reduce CO_2 levels in the atmosphere.

About RESCUE

The ability to design long-term mitigation scenarios is hindered by uncertainty regarding the effectiveness and environmental impacts of large-scale CDR implementations. Hence, RESCUE seeks to:

1. Develop a portfolio of CDR scenarios for the 21st century and beyond, so that scientists and policymakers can understand how the climate and the Earth System will respond to Global Mean Temperature stabilisation.

2. On the basis of these scenarios, assess the potential role of CDR in reducing net greenhouse gas GHG emissions, as well as its environmental impacts, side effects, and potential co-benefits.

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