Direct Air Capture with Carbon Storage

A process that removes CO_2 directly from the atmosphere

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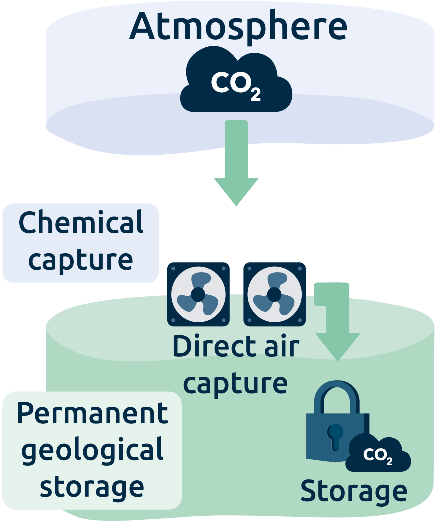

Expected permanence	millennia
Reversal risk	low
Uncertainty in amount of initially captured carbon	low
Uncertainty in amount of carbon stored over time	low
Ease and accuracy of MRV	high
Key co-benefits	none

What is direct air capture with carbon storage and how does it store carbon?

Direct air capture with carbon storage (DACCS) refers to the chemical extraction of CO_2 from the atmosphere by chemical adsorption, followed by the recovery and compression of CO_2 into a concentrated liquid, and storage in geological reservoirs. It is an example of removals with easy MRV because the capture and storage processes are relatively easy to quantify and measure. The process to separate CO_2 from the other components of ambient air is either done through absorption or adsorption. Once extracted, the carbon is then stored in geological reservoirs such as saline aquifers, or in other mineral forms in the Earth's crust.

Solid sorbent and liquid solvent DACCS are two common approaches used to capture CO_2 directly from the air. In the liquid solvent DACCS process, high-grade heat (900°C) is supplied by natural gas or hydrogen, with electricity sourced from the power grid. CO_2 emissions resulting from natural gas combustion are assumed to be captured within the plant limits. In the solid sorbent DACCS process, heat and electricity are both obtained from the power grid, using an industrial heat pump which converts electricity to low-grade heat (100°C). Newer capture technologies use more economical, reversible carbonate-based chemical reactions (carbonation and calcination), which are cheaper. As of February 2024, there are over 20 DAC/DACCS initiatives in Europe. Current capacity at one of the largest plants in operation (ORCA) is on the scale of 4000 tons of CO_2 each year.

Relevant regulatory framework:
Geological storage is currently regulated under the EU CCS Directive (2009/31/EC). According to the IEA, potential cross-boundary CO_2 transport may be regulated under the London Protocol, once ratified, or by other options that align with applicable international law.

ADVANTAGES

PERMANENT STORAGE

Sequested carbon is stored permanently with low risk of reversal.

TRL

DACCS is one of the more developed technologies (TRL 6). It is already being piloted.

MRV

Easy to quantify how much carbon is removed and stored. Baseline definition is straightforward and DACCS is, by default, considered additional.

ENVIRONMENTAL BENEFITS

Low impacts on terrestrial biosphere, generally not constrained by biophysical limitations and may provide valuable freshwater source in arid regions.

CHALLENGES

ENERGY INTENSIVE

Dependent on plentiful (and renewable) energy and heat source. Approximately 200mk^2 of non-arable land is needed for renewable energy generation to remove 1 Gt of CO_2.

PLANT LOCATION

Limitations on plant location due to necessary proximity to renewable energy supply. Storage capacity limited due to low current capacity of stable and permanent storage reservoirs.

COST

Costs are high and infrastructure is expensive to build.

FEW CO-BENEFITS

DACCS has fewer associated co-benefits compared to land-based sequestration.

What is the sustainable potential of DACCS to sequester carbon?

Economic performance

CapEx
Relies on costly grid and electricity transmission expansion, CO_2 pipelines and storage facilities.

OpEx
High energy costs (heat, power) and high cost of CO_2 transport and storage.

Environmental performance

Large amounts of minerals and metals are required for renewable energy infrastructure, which can impact water/air quality

Estimated scale and cost (2050)

5-40 GtCO_2/yr
\$100-300/tCO_2

Resource security

Requires substantial additional clean and renewable energy source.

Sustainability of sorbent materials depends on the material lifetime and CO_2 uptake efficiency.

Social and governance performance

The type of energy source can incur human health impacts (water consumption, fine particle pollution).

Social barriers to large-scale DACCS include plant locations, risks to local energy security, as well as associated impacts of rare earth metal mining.

Current unknowns and future research perspectives

DACCS is currently expensive and its future cost is hard to predict. Experts believe that economies of scale, process optimisation, including the development of more efficient and less costly sorbents, will eventually decrease sorbent fabrication costs. Greater availability and subsequent lower cost of renewable energy, could significantly reduce the energy costs of the technology. Options include novel configurations/tech that use carbonation cycles rather than sorbent materials.

Regulation is currently limited to CO_2 storage in geological storage sites under the EU CCS Directive (2009/31/EC), which also sets out clear liability and monitoring mechanisms. However, clear international or European regulatory framework for the cross-boundary transport of carbon has not yet been developed.

Policy recommendations

Support renewable energy development to ensure DACCS-related energy requirements can be accommodated, as opposed to further straining energy demand on partially-renewable energy systems. This avoids harmful health impacts arising from non-renewable electricity generation.

Acknowledge the uneven distribution of domestic capacity for renewable energy and permanent carbon storage for DACCS. Prioritise DACCS in regions where renewable energy is plentiful and ensure that the energy required for DACCS does not detract from grid decarbonisation. Ideally, locate DACCS plants in proximity to geological storage sites.

Coordinate transboundary CO_2 transport and storage to achieve DACCS deployment at scale. Create legal instruments that include socio-political and ethical compensation or incentivisation mechanisms for Member States that are expected to host optimal DACCS. Respect sovereign rights to equity and development in transboundary initiatives with third countries.

Ensure that policies coordinate key industries involved in capture, storage and transport of CO_2 and give certainty to stakeholders, incentivise financial investment and establish secure business models.

Relevant literature

Cobo et al. 2022

OECD/IEA report “Carbon Capture and Storage and the London Protocol” 2011

NEGEM Deliverables: D1.5, D2.1, D3.8, D3.9, D4.5, D5.2, D5.4, D6.3, D7.2, D8.2

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