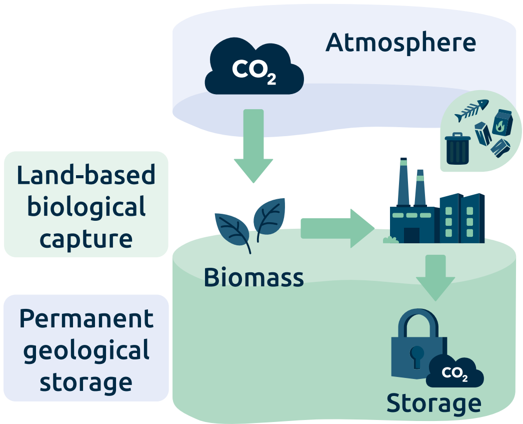
Biomass with Carbon Capture and Storage

NEGEM

A process that can remove carbon or reduce CO_2 emissions



Expected permanence	millennia
Reversal risk	low
Uncertainty in amount of initially captured carbon	medium
Uncertainty in amount of carbon stored over time	low
Ease of MRV	high
Key co-benefits	Energy production (heat, electricity, fuels)

What is BioCCS and how does it store carbon?

Biomass with carbon capture and storage (BioCCS) converts the CO_2 sequestered in biomass into energy, fuels, or other uses. The carbon released during this process is captured and stored in permanent geological storages. The selected biomass source and conversion pathway differ depending on the BioCCS project at hand, which in turn influences the CDR potential. The biomass source may be forest or agricultural residues, pulp and paper industry, wood pellets, solid municipal waste or dedicated crops, whilst conversion pathways involve biological or thermochemical processes. In this sense each BioCCS plant is unique, involving a specific feedstock, supply chain, CO_2 capture process and downstream processes.

Biomass used in BioCCS is often "zero-rated" meaning the carbon the biomass captured while growing is considered emitted upon harvest (accounted for under LULUCF emissions accounting). Any biogenic CO_2 captured from biomass conversion in a BioCCS plant is then automatically considered a negative emission. Existing point source biogenic CO_2 emissions (e.g. pulp and paper) can also be captured.

There are currently 19 bioenergy production facilities around the world either in operation, piloting or under construction. Some leading projects in the field include Drax and Stockholm Exergi with the intention of capturing 8 Mt CO_2/yr and 0.8 Mt CO_2/yr respectively (see D5.4) followed by permanent geological storage.

Relevant regulatory frameworks: Biomass feedstock sourcing should comply with EU Renewable Energy Directive 2018/2001 (L328/82) guidelines for sustainable biomass.

ADVANTAGES

CHEAP RETROFITTING
CCS can be applied to existing point sources of biogenic CO_2, such as paper mills, ethanol plants and biomass power/CHP plants. This makes it cheaper, whilst contributing to energy security.

PERMANENT STORAGE
Sequestered carbon is stored permanently with low risk of reversal.

MRV
Protocols for monitoring, reporting and verification already exist.

PRODUCTION OF USEFUL BY-PRODUCTS
Energy in the form of heat, electricity or fuels are produced during the biomass conversion. This decreases the energy footprint of BioCCS and can offer additional revenue streams.

CHALLENGES

HIGH VALUE CHAIN EMISSIONS
Long distances between biomass source, processing and storage sites result in higher emissions along the entire value chain.

PLANETARY BOUNDARY PRESSURE
Large-scale deployment from dedicated bioenergy crops severely conflicts with planetary boundaries and biodiversity goals. Biomass crops require vast amounts of water, fertiliser and land, competing with food security, whilst raising food prices.

HIGH INDIRECT GHG EMISSIONS
Associated deforestation and indirect land-use change emissions can be high. Since the demand for food and feed crops remains, more food and feed is produced elsewhere and just displaces where emissions occur.

LONG CARBON PAYBACK TIMES
Carbon debt payback time can be long depending on biomass source.

IMPERFECT CARBON CAPTURE RATES
Not all carbon from bioenergy conversion can be directly captured (capture rates ca. 90-99%).

LEAKAGE POTENTIAL
Potential leakage during biomass transport, particularly if biomass used and produced in different regions.

What is the sustainable potential of BioCCS to sequester carbon?

Economic performance

CapEx
Lower costs for retrofitted plants.

OpEx
High costs to process CO_2 and transport to storage site. Costs lower for highly concentrated CO_2 streams within BioCCS plants.

Environmental performance

Land-use change, biosphere integrity, freshwater impacts and nutrient flows are impacted less by non-dedicated energy crops or by utilising biomass side-streams (agricultural/forestry residues).

Water and land requirements are higher for plantation-based BioCCS.

Estimated scale and cost (2050)

0.5-11 $GtCO_2$/yr
\$15-400/tCO_2

Resource security

Lower energy constraints if energy produced in biomass conversion can be utilised.

Additional dedicated energy crops for biomass production require new land conversion and water for irrigation.

Social and governance performance

Potential need for international biomass transport and impact on food systems due to additional land area requirements.

BioCCS is perceived unfavourably by stakeholders.

Current unknowns and future research perspectives

The future availability of non-plantation based feedstock is uncertain, and the limited amount will need to be shared amongst other potential feedstock uses (e.g. construction materials, biochar or alternative fuel production). Climate change may impact biomass growth rates and constrain future feedstock quantity.

There is uncertainty in the CDR potential and BioCCS cost as a technology due to the lack of a standardised methodology. Clarity is needed on feedstock value chain carbon accounting as uncertainty exists as to whether they create net-negative emissions.

Carbon storage availability is currently low and the benefits/risks of on/offshore storage are still being studied.

Policy recommendations

Ensure that certification schemes provide appropriate incentives to securely capture of all concentrated CO_2 streams regardless of carbon emission type (fossil, biogenic); apply carbon accounting throughout the entire value chain to enable a systemic assessment of each BioCCS project and determine the net removal of carbon.

Conduct system-level BioCCS project life-cycle impact assessments to determine impacts on land-use change, natural resources, ecosystem health, biodiversity, nutrient flows and soil carbon stocks, measured against potential trade-offs with planetary boundaries and the achievement of Sustainable Development Goals.

Develop policies that support a transition towards plant-based diets e.g. EAT-Lancet planetary health diet that repurposes pastureland and alleviates land resource demand.

Prioritise sustainable feedstock sources such as municipal waste, forestry and agricultural residues, and pulp and paper mills to avoid further transgression of planetary boundaries. Prohibit high quality and high value biomass as a feedstock in bioenergy.

Source feedstock biomass sustainably, in full compliance with EU and international regulations; ensure that biodiverse ecosystems are not converted into biomass plantations. Use limited biomass sources in hard-to-abate sectors where no other appropriate feedstocks are available.

Foster international trade and cooperation to address uneven distribution of domestic capacities such as biomass resources and storage sites.

Relevant literature

- Cobo et al. 2023
- EU Directive for use of energy from renewable resources
- Heck et al. 2018
- NEGEM Deliverables

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