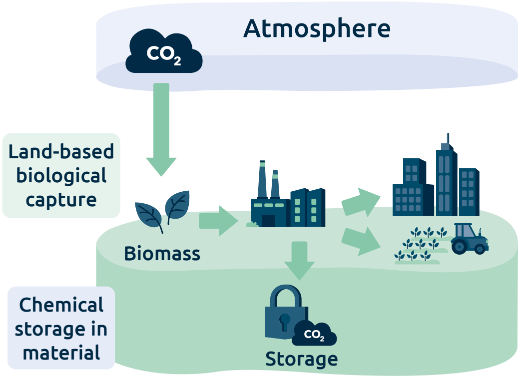
Biochar

NEGEM

A material that stores carbon and can reduce CO_2 emissions



Expected permanence	decades to millennia
Reversal risk	medium
Uncertainty in amount of initially captured carbon	low
Uncertainty in amount of carbon stored over time	high
Ease of MRV	medium
Key co-benefits	increased crop yields, reduced soil N_2O emissions, soil pH, reduce use of synthetic fertiliser

What is biochar and how does it store carbon?

Biochar is produced through the thermal decomposition of biomass in the absence of oxygen, in a process called pyrolysis, at a feasible temperature range between 450°-600°C. Heating levels above this range can create liquid form ‘bio-oil’ and ‘pyrogas’.

Biomass can be obtained from a variety of sources, such as urban and municipal waste of agricultural, plant and forestry residues as well as dedicated biomass crops, and its quality determined by its feedstock source and the temperature at which it was produced. For example, a woody feedstock that was heated beyond 450°C has greater stability and a lower decay rate than manure-derived feedstock, heated at a lower temperature.

Permanence and reversibility are dependent on labile and recalcitrant carbon fractions, storage, and storage medium CDR. Biochar can be added to construction material, such as cements and tar, or can be added to soils as it enriches the natural soil carbon sink. Research has shown that the recalcitrant portion of biochar is highly stable, however, due to a lack of long-term field studies the potential release of stored carbon in biochar over time periods relevant for CDR is unclear.

According to the latest European Biochar Industry report, by the end of 2023, biochar production reached around 49 000 t (equivalent to over 130 000 t CO_2e).

Relevant regulatory frameworks: Regulation on an EU certification for carbon removals; Renewable Energy Directive; Land Use, Land-Use Change and Forestry Regulation; Regulation for the purpose of adding pyrolysis and gasification materials as a component material category in EU fertilising products as a fertiliser.

ADVANTAGES

MULTIPLE CO-BENEFITS

Biochar properties (e.g. high porosity) provide a range of co-benefits for agriculture, such as increased soil nutrient and moisture retention.

MIXED FEEDSTOCK

No separation of feedstock types is required throughout the pyrolysis process.

SMALL-SCALE DEPLOYMENT

Can be widely and rapidly deployed through multiple small-scale plants, utilising locally sourced and sustainable biomass side-streams.

COST-EFFICIENT

Economic viability is high. For example, co-produced syngas and bio-oil can be sold for profit, generating revenue to the plant operators.

CHALLENGES

STANDARDISED CERTIFICATION CHALLENGING

The numerous storage options for biochar makes a standardised approach to certification of permanently stored carbon with certainty challenging.

LESS CDR EFFICIENT

Lower CDR efficiency than other negative emission technologies and practices due to carbon lost during pyrolysis process and decay.

SUSTAINABLE FEEDSTOCK COMPETITION

Overall biomass demand will increase, leading to competition with other biomass-based NETS such as BioCCS.

HARD TO MONITOR

Permanence of carbon storage biochar and reactivity in open field applications is still unproven. Applied over a large area it is difficult to monitor the dispersed storage of extracted CO_2 and adhere to MRV requirements with certainty.

ECOSYSTEM DEPENDENT CO-BENEFITS

Agricultural benefits are dependent on the soil and properties of the biochar, climate conditions and the interaction between these.

POTENTIAL CLIMATE FEEDBACKS

Albedo changes may result, depending on the application method and the land on which biochar is applied.

What is the sustainable potential of biochar to sequester carbon?

Economic performance

Cheaper than other NETPs.

CapEx
Cost of leasing land, materials, machinery and trucks, feedstock, energy.

OpEx
Labour (farmer or pyrolysis operator), maintenance, and utilities.

Environmental performance

Biosphere integrity and land use change where wood or purpose grown crops are used as feedstocks.

Intensive freshwater use when biomass pyrolysis is based on feedstock from irrigated plantations.

Estimate scale and cost (2050)

0.3- 6.6 $GtCO_2$/yr
\$10-345/tCO_2

Resource security

Purpose grown plantations place pressure on land and own crops and large-scale biomass consequently, food security.

Risk of water scarcity for other uses e.g. food production.

May produce energy and useful products (pyrogas, biooil).

Social and governance performance

More resilient soils will secure livelihoods.

Allows for local, bottom-up infrastructure, and is therefore less dependent on biomass prices.

Current unknowns and future research perspectives

Reactivity of biochar in different storage mediums (e.g. soils, buildings materials, concrete, asphalt, tar) and the proportion of labile (chemically unstable) and recalcitrant (stable) biochar carbon retained in storage medium e.g. soils over long time periods.

Interaction between biochar and soil properties at the application site and the influence on total carbon loss (i.e. from soil organic carbon stocks and biochar degradation).

Interaction between biochar and soil properties at the application site and the influence on ecosystem co-benefits of biochar application in different soil types e.g. water-holding capacity, crops, yield, climate conditions, non-CO_2 GHG emissions, and binding of heavy-metal pollutants.

Policy recommendations

Design long-term duration field experiments to provide an increased understanding on biochar properties, functions, and to help develop a comprehensive biochar application policy.

Ensure that the addition of biochar to soil suits the application context by, amongst others, considering climate and soil conditions. Create a regulation with a robust methodology that monitors dispersed storage, potential albedo change, accounts for decay rates and emissions, and assigns liability for reversal.

Ensure that biomass is sourced from side streams such as agricultural and forestry residues, or food waste to avoid accumulating a carbon debt, taking land away from nature, competition with other NETPs, or food insecurity.

Avoid growing dedicated crops; prioritise growth in abandoned cropland or apply a land- and calorie-neutral pyrolysis system that requires fewer fertilisers, pesticides and irrigation, while providing co-benefits.

Relevant literature

- CDR Primer
- European Biochar Market Report 2023/2024
- State of CDR
- NEGEM Deliverables NEGEM Deliverables: D1.2, D3.2, D3.8, D3.10, D4.5, D6.3, D7.2

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