



IEA Bioenergy

Technology Collaboration Programme



Biochar as a Carbon Storage Solution

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IEA Bioenergy, Task 33 (Gasification)

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by **iea**

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- PhD, Vienna University of Technology
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- Austrian Representative, IEA Bioenergy Task 33 - Gasification, since 2010
- Task Leader, IEA Bioenergy Task 33, since 2025
- Member of several scientific boards
- Research focus: Thermochemical conversion processes, focus on pyrolysis and gasification

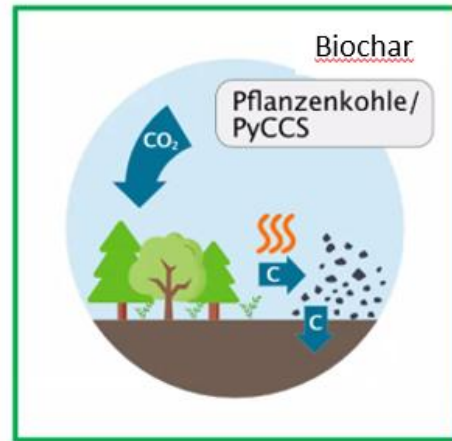
Options for negative emissions

Considered as promising tools for the CO₂ reduction

Afforestation

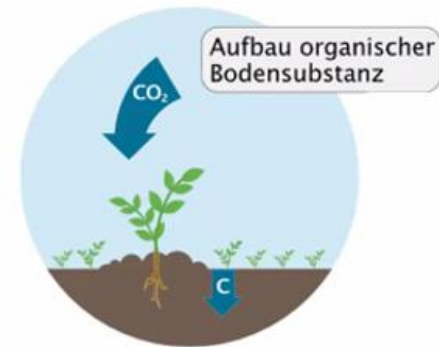


Biochar



PyCCS =
pyrolytic
carbon
capture and
storage

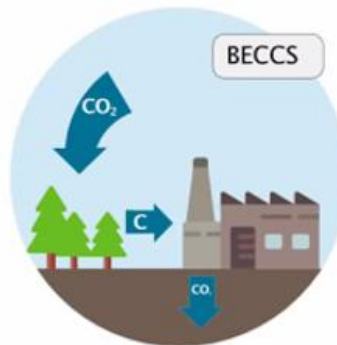
Soil organic carbon increase



Enhanced
Weathering

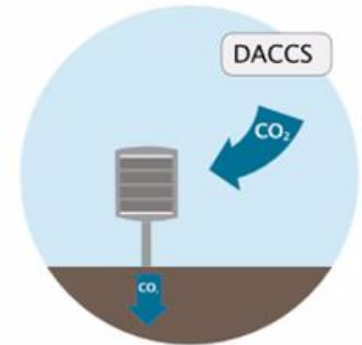


BECCS



BECCS = bioenergy carbon
capture and storage

DACCS

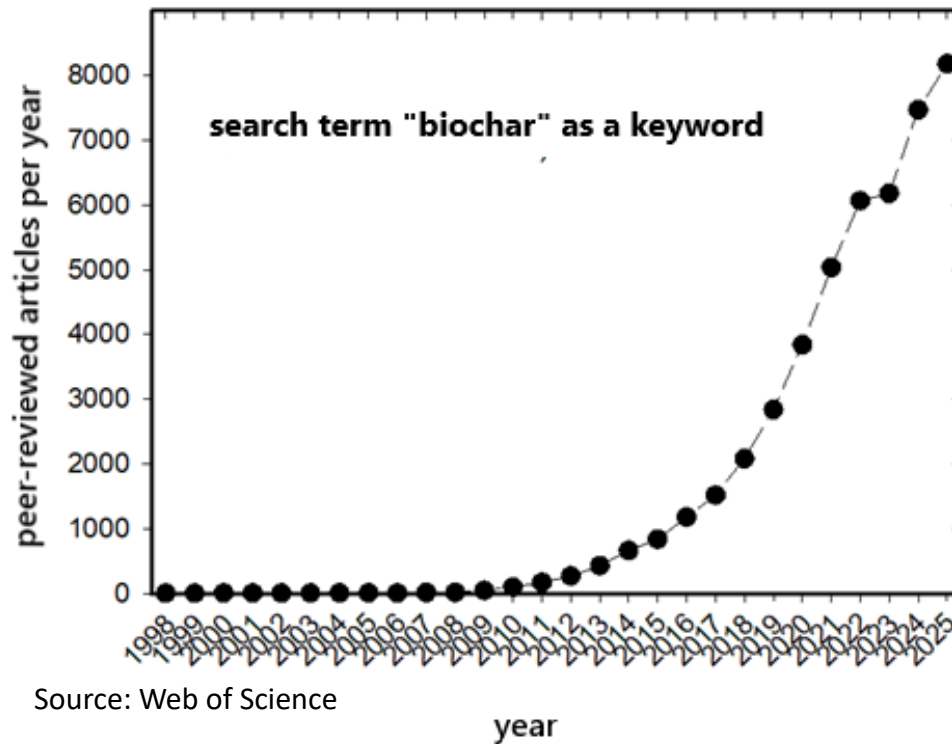


DACCS = direct air capture
and carbon storage

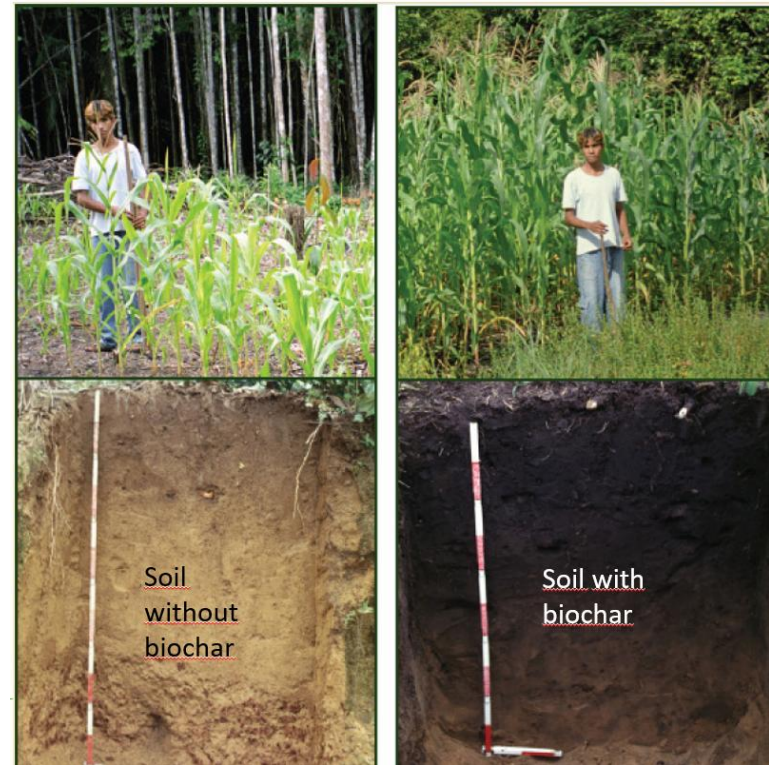
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Biochar

Biochar is a carbon-rich solid material produced during the thermochemical conversion of biomass

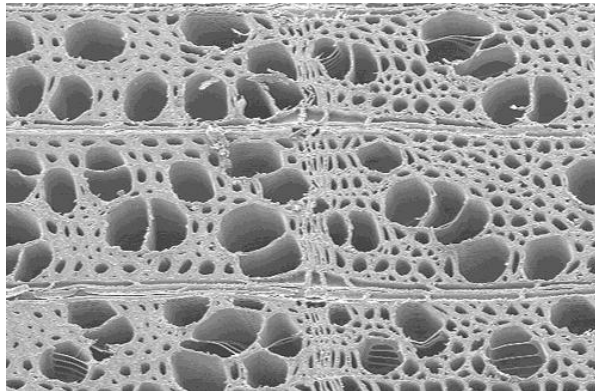


Source: Web of Science



Charcoal has been used to improve soil fertility already in early societies.

How is biomass converted during pyrolysis/gasification

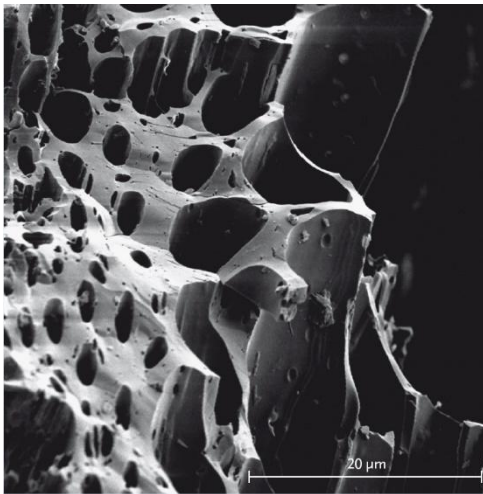


Porous structure of plant material is conserved
AND
Additional micropores are created

Consequences: high specific surface area, high sorption capacity

Chemistry: H and O are released in volatile compounds, C is enriched → **Carbonisation.**

Results in degradation-resistant, robust C-compounds (highly condensed and aromatic structure)



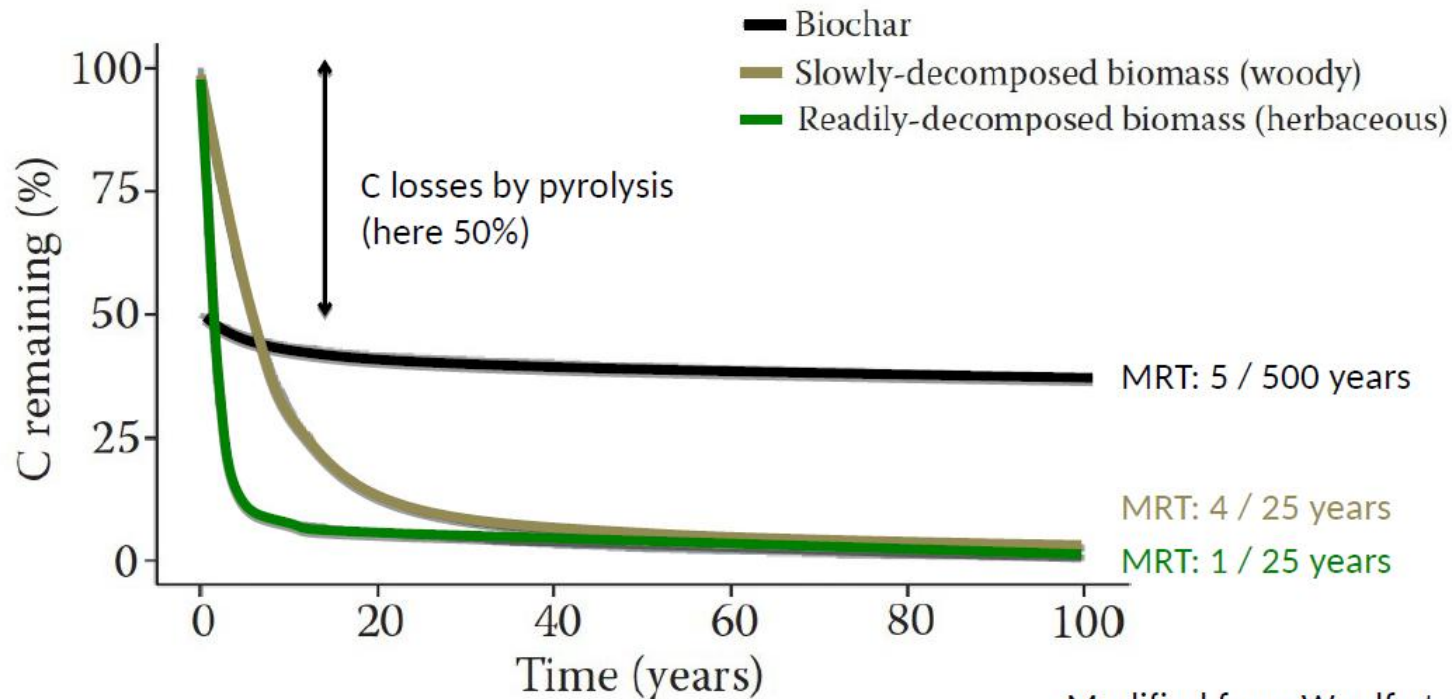
Biogenic residues to slow down climate change

- Residues from
 - Agriculture
 - Forestry
 - Horticulture
 - Food production and consumption
- Processed to
 - Compost
 - Anaerobic digestates
 - Sewage sludge
 - Biochar as (by-) product



Decomposition of biomass

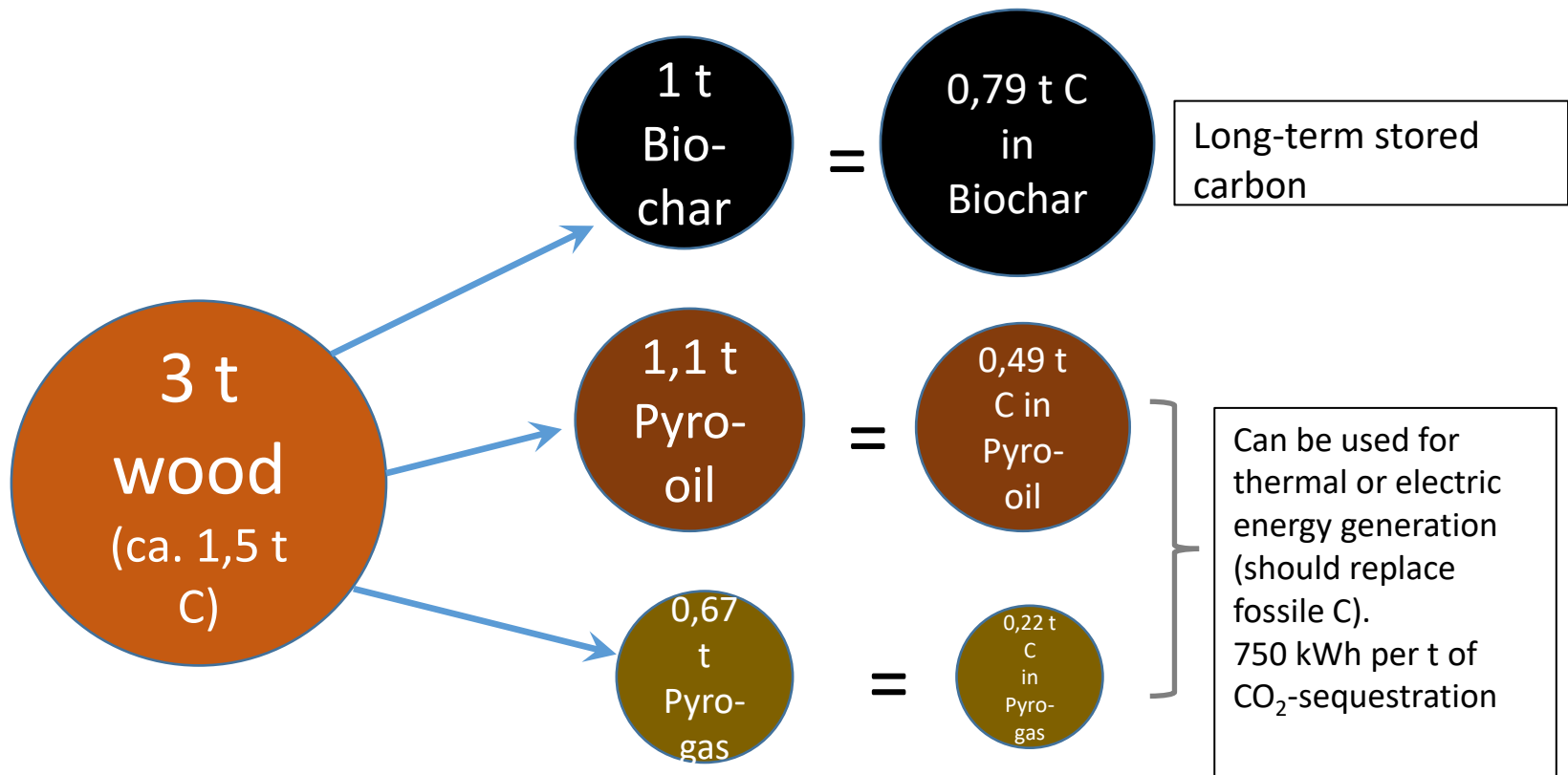
Mean residence time (MRT) depends on type and conversion of biomass



Modified from Woolf et al., 2018

plant biomass is rapidly decomposed and released as CO₂ back to the atmosphere

Carbon removal with biochar (pyrolysis)



- Average costs for CO₂-capture with (pyrolysis) biochar:

179 USD / t CO₂

Sources: <https://carboncredits.com/>,
<https://www.carbonfuture.earth/>

- Average CDR*-costs with other technologies:

388 USD / t CO₂

*CDR = carbon dioxide removal
www.ieabioenergy.com

CO₂-compensation with biochar?

Average annual CO₂-footprint per person in Austria (2022):



8,1 t CO_{2-e}

Necessary mass of biochar for compensation:

$x = 8,1 / (\text{C-concentration} * \text{molar ratio} * \text{losses in transport and processes})$

$x = 8,1 / (0,79 * 3,67 * 0,92)$

$x = 3,0$

3,0 t

biochar → requires about 9-10 t dry feedstock!

Population of Austria: 9,2 Mio. → would require 28 mio. t biochar for complete CO₂-compensation

(European production 2024: ca. 70.000 t biochar) → by far too small

Austria: 1,32 Mio. ha arable land → 21,2 t biochar per ha annually is by far too much → Austria does not have the necessary areas for distribution

Is there a chance that biochar will contribute significantly to net-zero?

- Estimations of biochar potential: globally 0,1 bis 6,6 Gt CO_{2e}/yr
- Neither biochar, nor any other technical CO2 removal -technology alone will be sufficient to achieve the total necessary contribution to net-zero

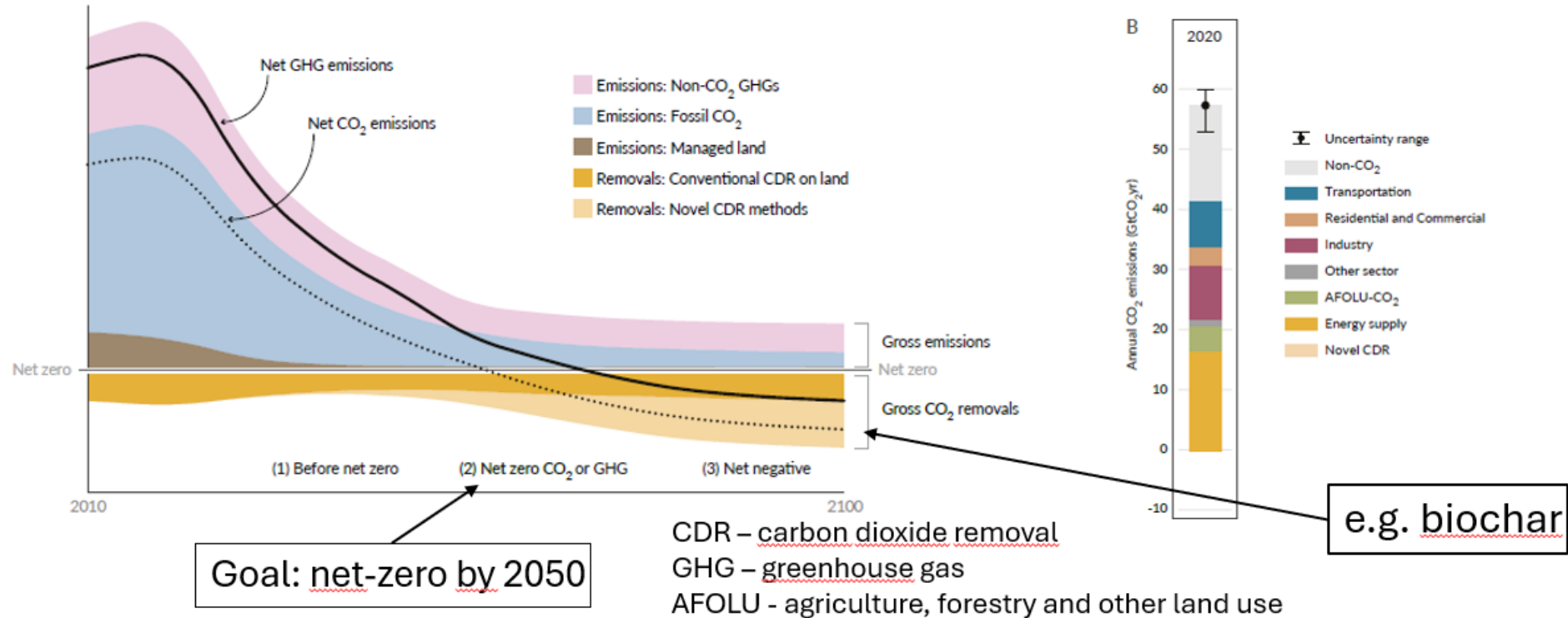
→ Only a COMBINATION OF ALL AVAILABLE NETs will keep the chance to reach net-zero alive!

→ Technology-openness is required!

Necessity of “Negative Emission Technologies” (NETs)

Reduction der greenhouse gas emissions ist indispensable, but not sufficient (to reach net-zero)
 The residual „hard to abate“-emissions must be compensated with NETs.
 Annual carbon dioxide removal (CDR) should be scaled from 2 to 10 gigatons annually.

Greenhouse gas emissions (stylised pathway)



Certified biochar

- EBC = European Biochar Certificate (voluntary standard)
 - Emphases: sustainable production, climate impact, contaminant limits, incl. Certification of production plants (process control)
- Austrian national standard
 - Focus on: product quality for soil application, compliance with Austrian environmental and waste rules, more application oriented



Austrian national standard

Certification of biochar carbon removals according to European standard (CRCF-framework)

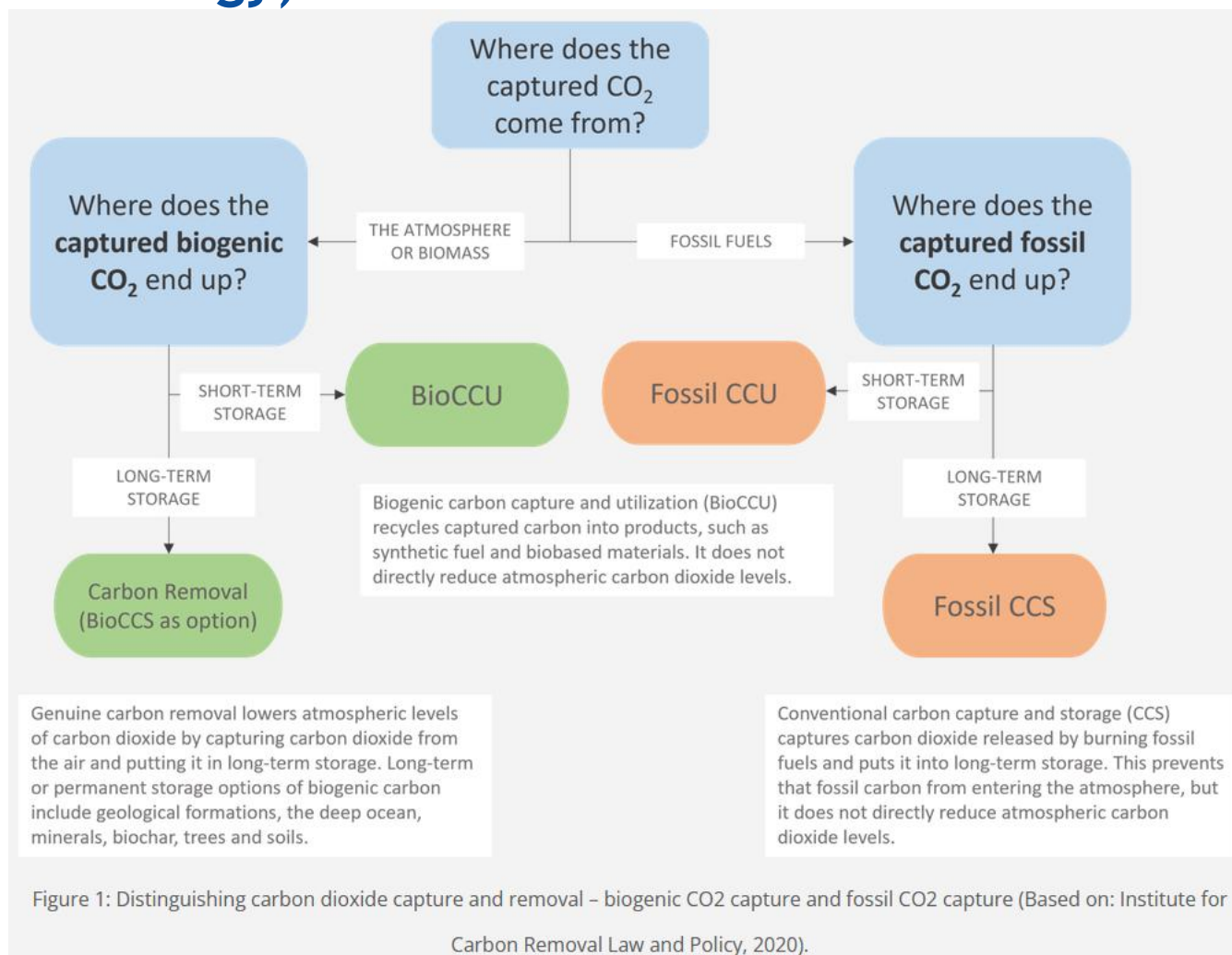


Pathways for biochar utilization

Soil & agricultural use	Industrial applications
Soil anmendment	Wastewater treatment
Horticulture (greenhouses)	Concrete additive
Composting	Asphalt additive
Soil remedation	Catalyst support
	Activated carbon precursor
	Industrial use e.g. conductivity, thermal resistance,...

BECCUS and Carbon Management

(IEA Bioenergy)



IEA Bioenergy

Publications on carbon management (selected)



Management of Biogenic CO₂: BECCUS Inter-Task Phase 3

Ongoing work

(including biochar as a carbon storage
medium)

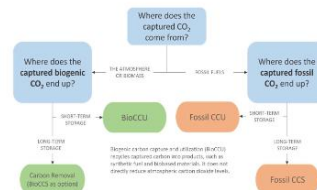


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The trade-offs between utilisation and storage of captured biogenic CO₂

IEA Bioenergy: Task 40
March 2026

Note: The presented information dates back to November 2025. In the meantime, there have been new developments in particular with regards to legislation.



Own figure, based on Institute for Carbon Removal Law and Policy, 2020; Explainer: Carbon Removal.



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BECCUS Science & Policy

WP7 Summary Report

Contribution of IEA Bioenergy Task 45 & Task 40 to Inter-Task Project (ITP)
Management of biogenic CO₂: BECCUS Phase 2

IEA Bioenergy: Task 45

May 2025



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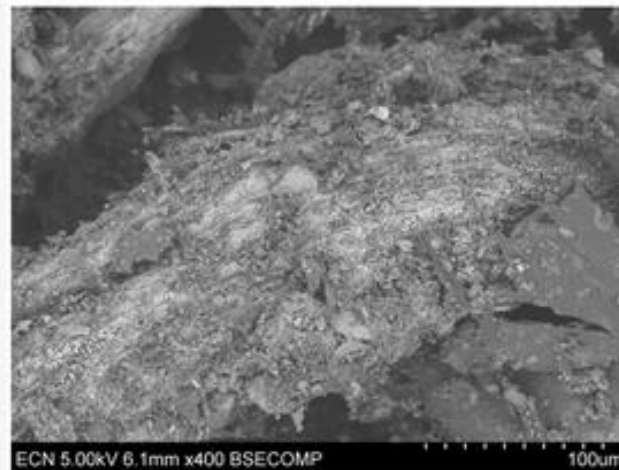
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Biochar comparison

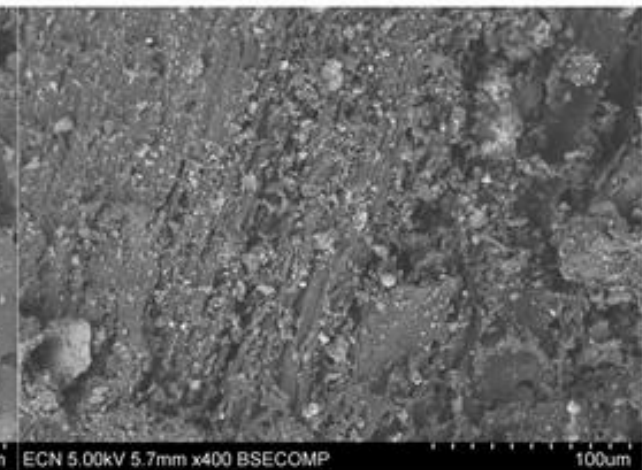
Slow pyrolysis / fluidized bed gasification

A – pyrol. 400°C, 60 min

B – pyrol. 600°C, 60 min



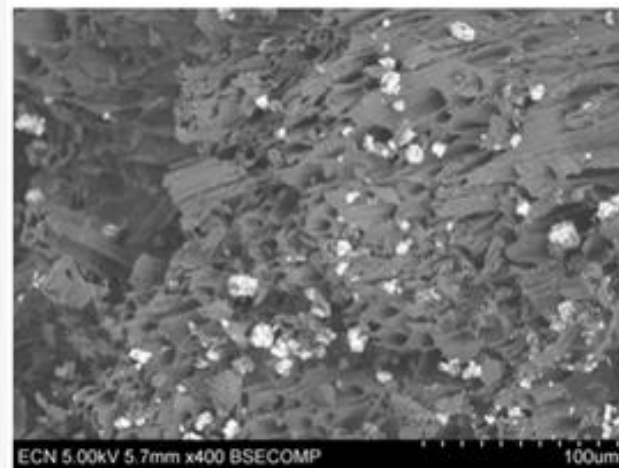
(a) Slow pyrolysis GHW 1 400 °C, 60min.



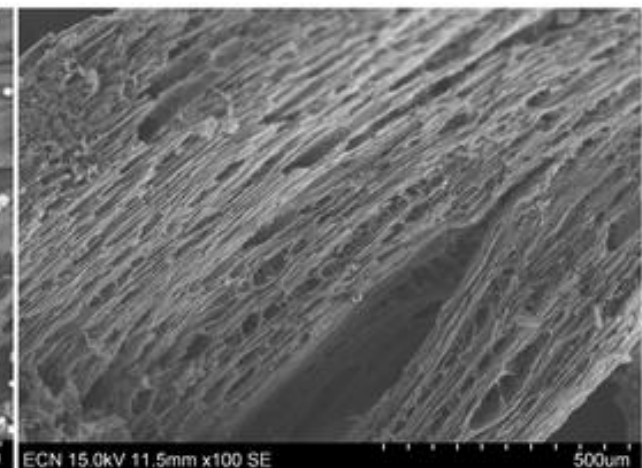
(b) Slow pyrolysis GHW 1 600 °C, 60min.

C – gasif. 600°C, air

D – gasif. 750°C, air



(c) Lab scale FB GHW 1, air, 600 °C.



(d) Lab scale FB GHW 1, air, 750 °C.

Biochar from pyrolysis and gasification - differences

Pyrolysis char = chemically active carbon
Gasification char = thermally hardened carbon

Main Property	Pyrolysis Biochar	Gasification Char	Why It Matters
Surface functional groups	High	Low	Controls nutrient retention, microbial activity, and chemical reactivity
Ash content	Lower	Much higher	Affects pH, salinity, mineral loading, and soil compatibility
Carbon structure (aromatic/graphitic character)	Less condensed	Highly condensed / graphitic	Determines stability, conductivity, and inertness
Porosity & water retention	Better microporosity and water holding	More thermally damaged/coarser pores	Important for soil moisture and microbial habitat
Chemical/biological reactivity	More reactive and biologically active	More inert and refractory	Influences soil response, aging behavior, and nutrient cycling

Concluding remarks

- Biochar provides a stable pathway for long-term carbon sequestration and climate mitigation.
- Pyrolysis-derived biochar typically exhibits higher porosity and greater surface functional reactivity and is more suitable for soil amendment and horticultural applications
- Gasification-derived char is more carbon-condensed and structurally inert and offers enhanced stability for long-term carbon storage applications (industrial appl.)
- Climate mitigation will not be achieved by biochar alone, but through the integrated use of multiple complementary technologies and strategies.

Thank you for listening!

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