



Biochar's Contribution Towards Net-Zero Economy

Prof. Ondřej Mašek

Chair of Net Zero Emission Technologies

UK Biochar Research Centre, University of Edinburgh

*ondrej.masek@ed.ac.uk





UK Biochar Research Centre University of Edinburgh

- **Established in 2009** to complement research on CO₂ capture and sequestration
- Focussed on integration of biochar in **bio-economy systems**
- Multi-disciplinary centre in collaboration of Schools of **GeoSciences**, Biology, Chemistry, and Engineering
- Member of the **European Biochar Industry Consortium (EBI)**

- Pyrolysis technology - Material engineering - Soil science – Bioenergy & biorefinery concepts - Environmental and sustainability assessments -



Unique ability to offer multiscale production facilities for biochar



What is biochar?

Biochar is the solid, carbon rich residue of biomass pyrolysis – think of charcoal



Miscanthus pellet biochar
[700°C]



Oak chip biochar
[550°C]



Sewage sludge biochar
[550°C]

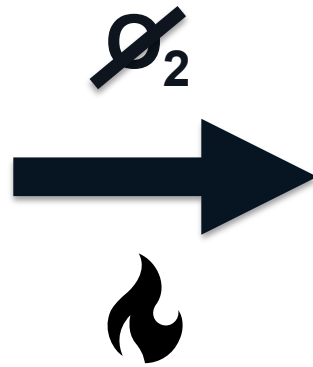
Biochar carbon removal

Pyrogenic Carbon Capture and Storage [PyCCS]

- CO₂ is first captured by plants
- The biomass is heated under oxygen-limited conditions to produce biochar
- Biochar sequesters the carbon in a solid form for centuries



Wood pellet

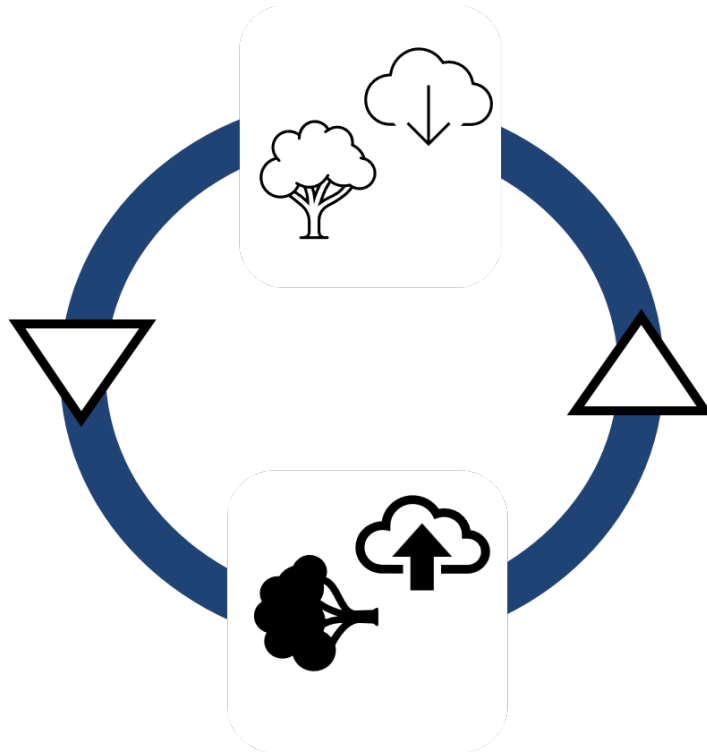


Wood biochar pellet

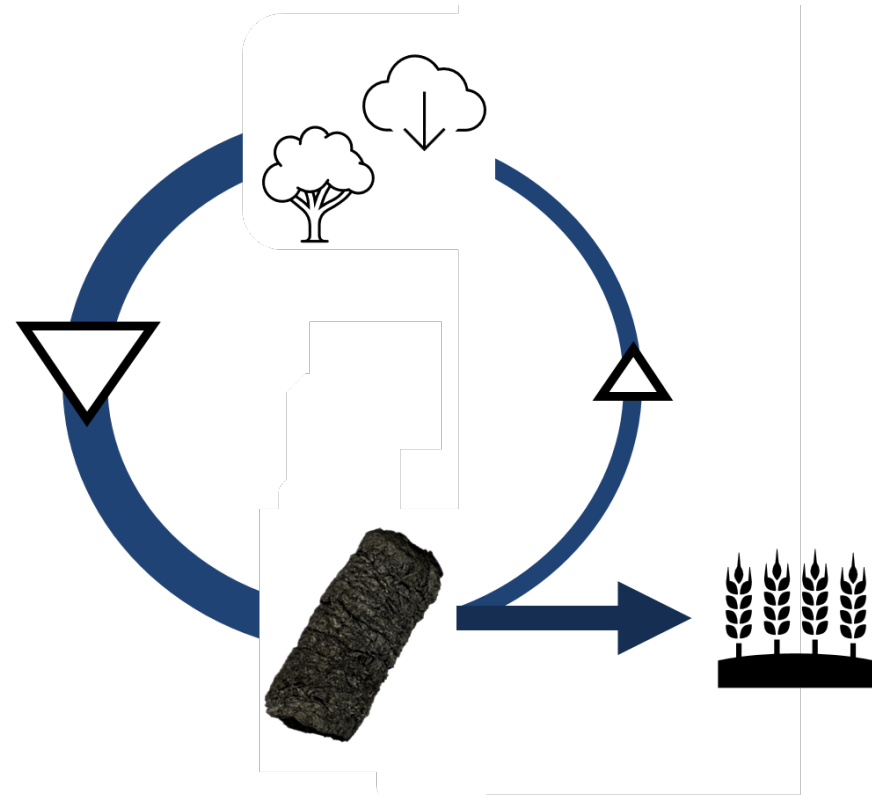
Biochar carbon removal

Pyrogenic Carbon Capture and Storage [PyCCS]

Biochar hacks the natural carbon cycle



**Natural biomass decay –
CO₂ re-released**



**Biochar carbon removal
from the natural cycle**

Biochar feedstock

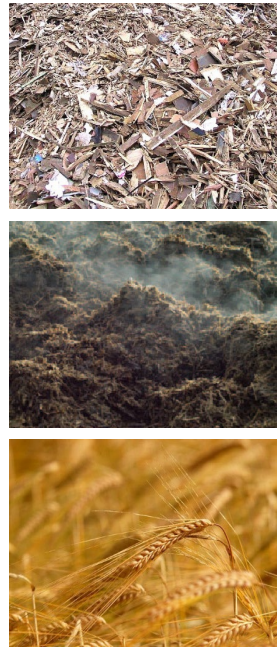
Virgin biomass – higher cost, competition with other uses



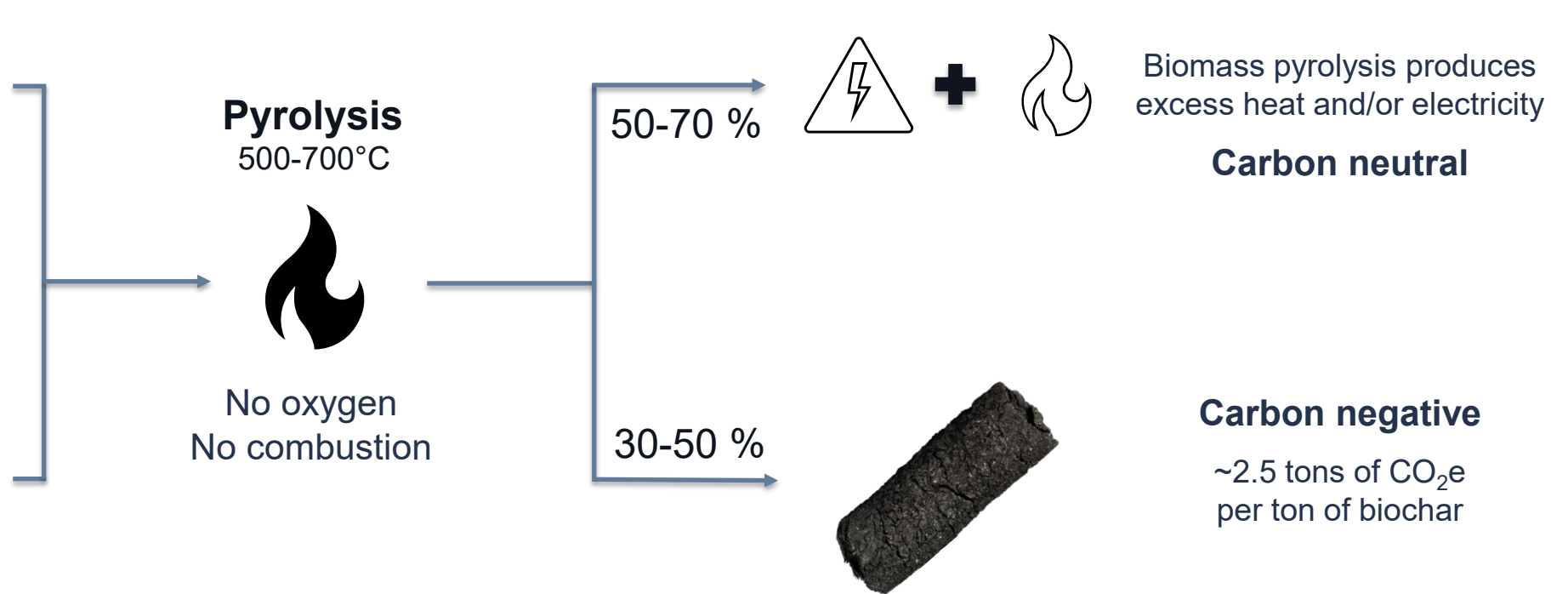
Non-virgin biomass – lower cost, more challenging properties, less competition with other uses, but competition still exists



Biochar production

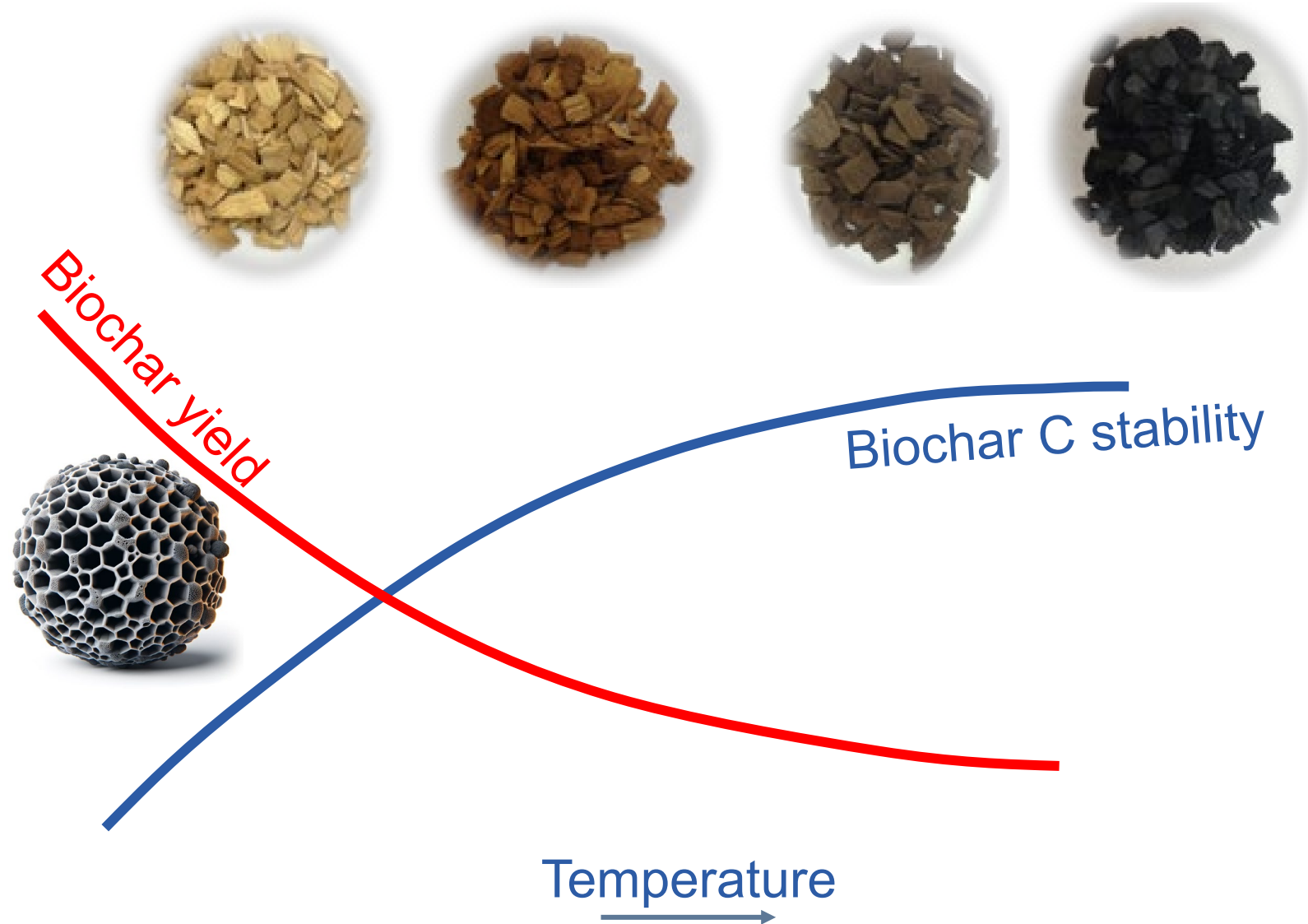


Sludge, manure, straw, trimmings, algae, RDF, MSW...



- Industrial production is energy-positive
- Pyrolysis reactors can be up or downscaled [500 - 50,000 t yr⁻¹]
- Decentralised deployment possible

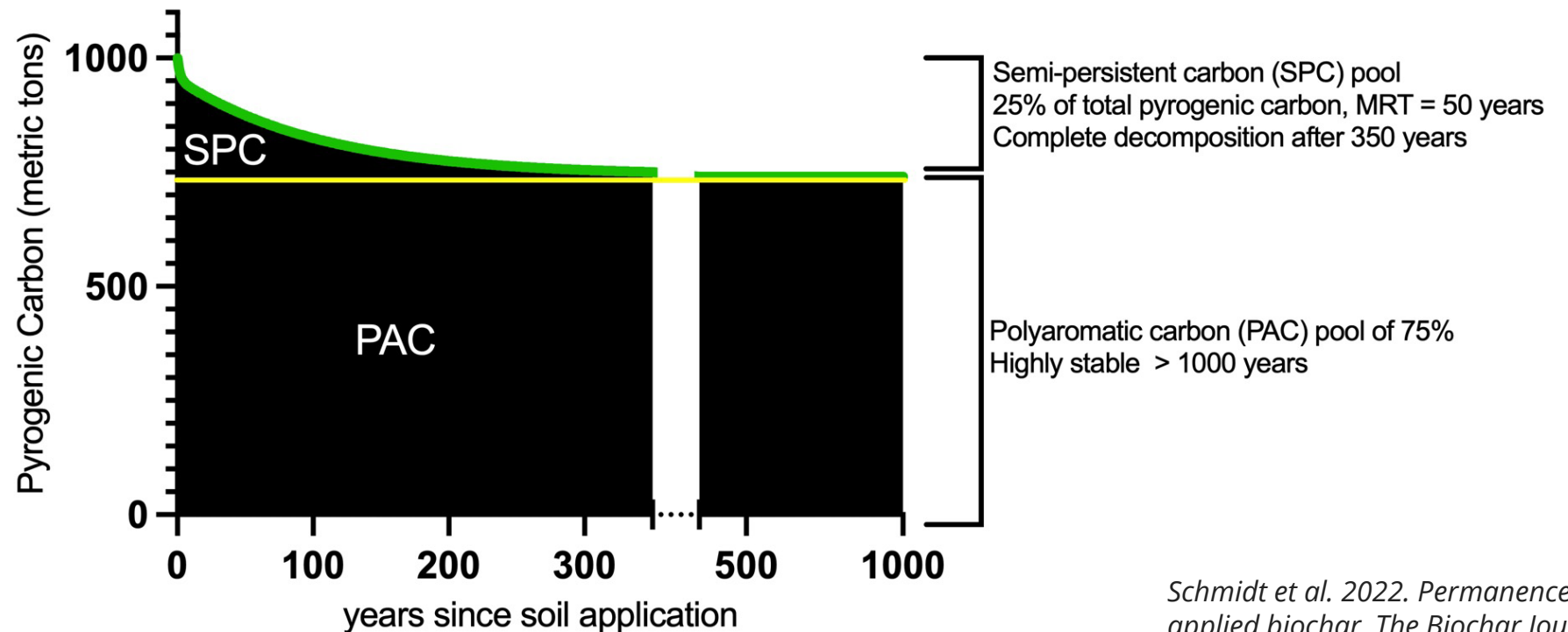
Biochar yield and stability



Biochar stability

Permanence

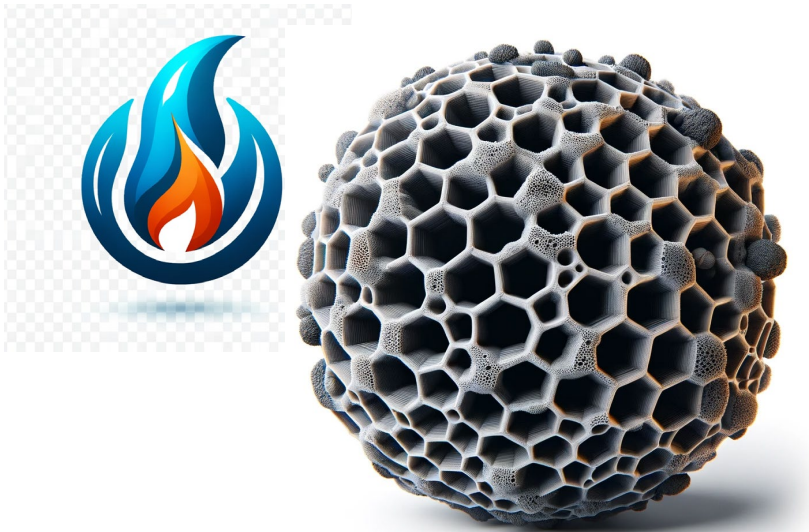
- Biochars generally consists of two carbon pools – semi-persistent and persistent
- The higher the production temperature – the more persistent the carbon
- Polyaromatic carbon will be stable on geological timescales



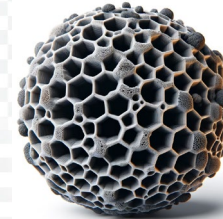
Schmidt et al. 2022. Permanence of soil applied biochar, *The Biochar Journal*.

Biochar production technologies

Main product

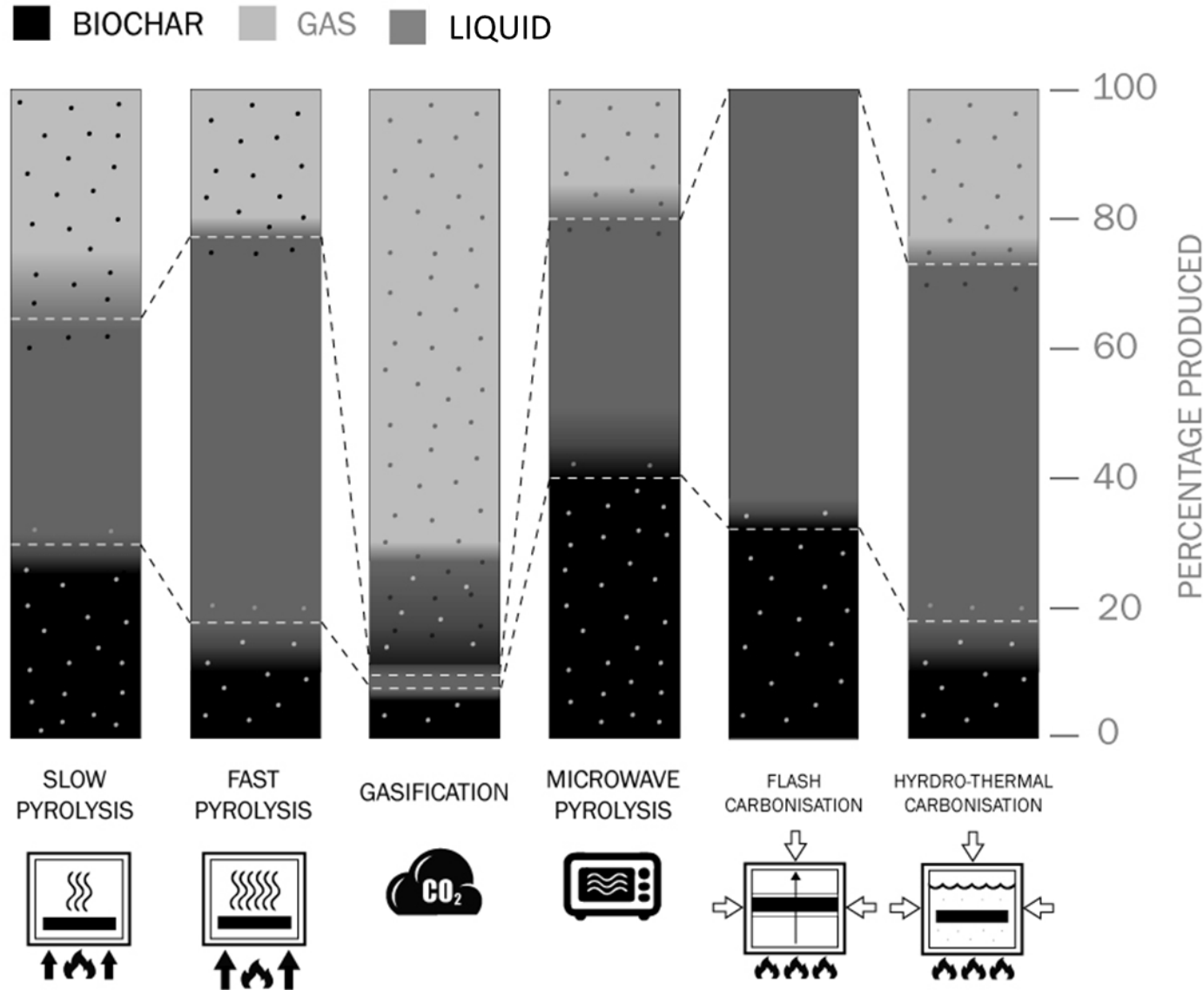


By-product



Different sets of opportunities and challenges

Biochar production technologies

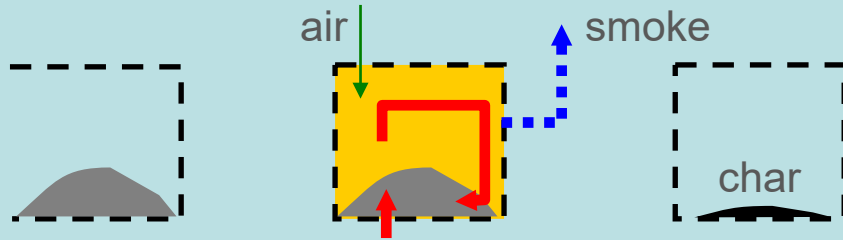


Source: Chapter 2 in Biochar in European Soils and Agriculture, Science and Practice, Routledge (2016)

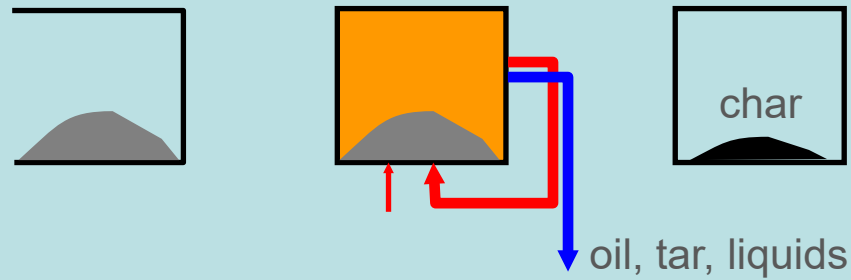


Biochar production scales

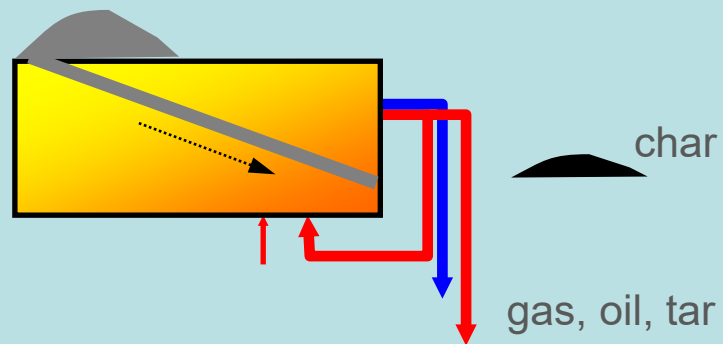
Traditional charcoal burning



Batch pyrolysis kiln

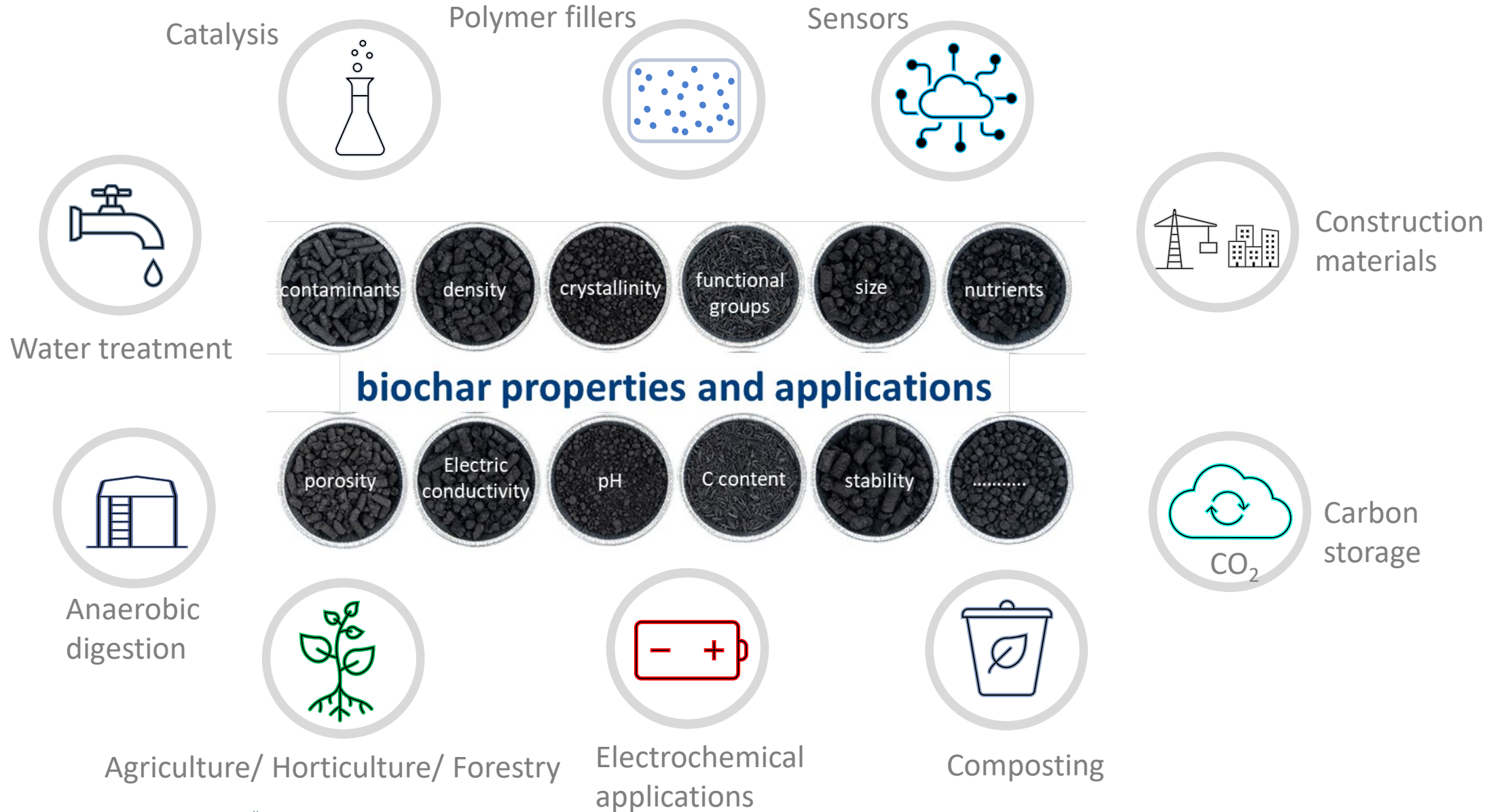


Industrial unit for continuous production





Biochar applications



Catalysis

Polymer fillers

Sensors



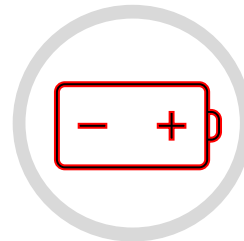
Water treatment



Anaerobic digestion



Agriculture/ Horticulture/ Forestry



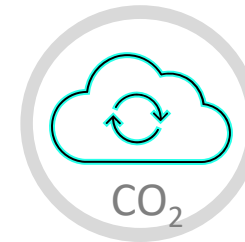
Electrochemical applications



Composting



Construction materials



Carbon storage



contaminants



density



crystallinity



functional groups



size



nutrients



porosity



Electric conductivity



pH



C content



stability



.....

biochar properties and applications





Biochar applications

Biochar properties can be **tuned** to match
the needs of **specific applications**



Biochar engineering

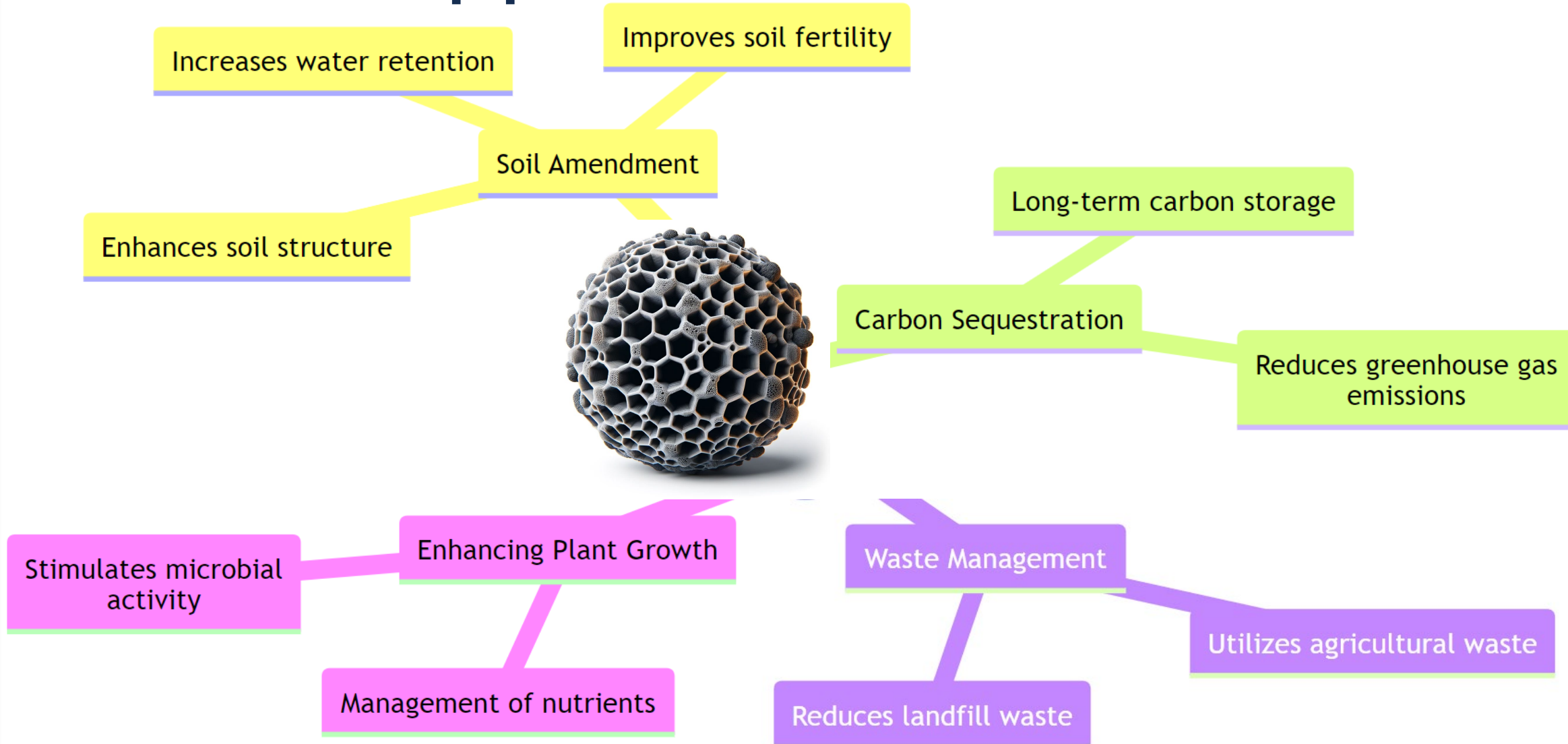
Options for modification of biochar yield and tuning of biochar properties

Biomass	Pre-treatment	Pyrolysis	Post-treatment	Additives
<ul style="list-style-type: none"> • Woody biomass • Herbaceous biomass • Algae • Organic residues • Husks • Sludges • ... 	<ul style="list-style-type: none"> • Milling • Grinding • Pelleting • Briquetting • Leaching • Acid washing • Extraction • ... 	<ul style="list-style-type: none"> • Temperature • Heating rate • Residence time • Volatile interactions • Mode of heating • Cooling • ... 	<ul style="list-style-type: none"> • Washing • Activation • Functionalisation • Pelleting • Doping • ... 	<ul style="list-style-type: none"> • Minerals • Nutrients • Microbes • Mycorrhiza • ...

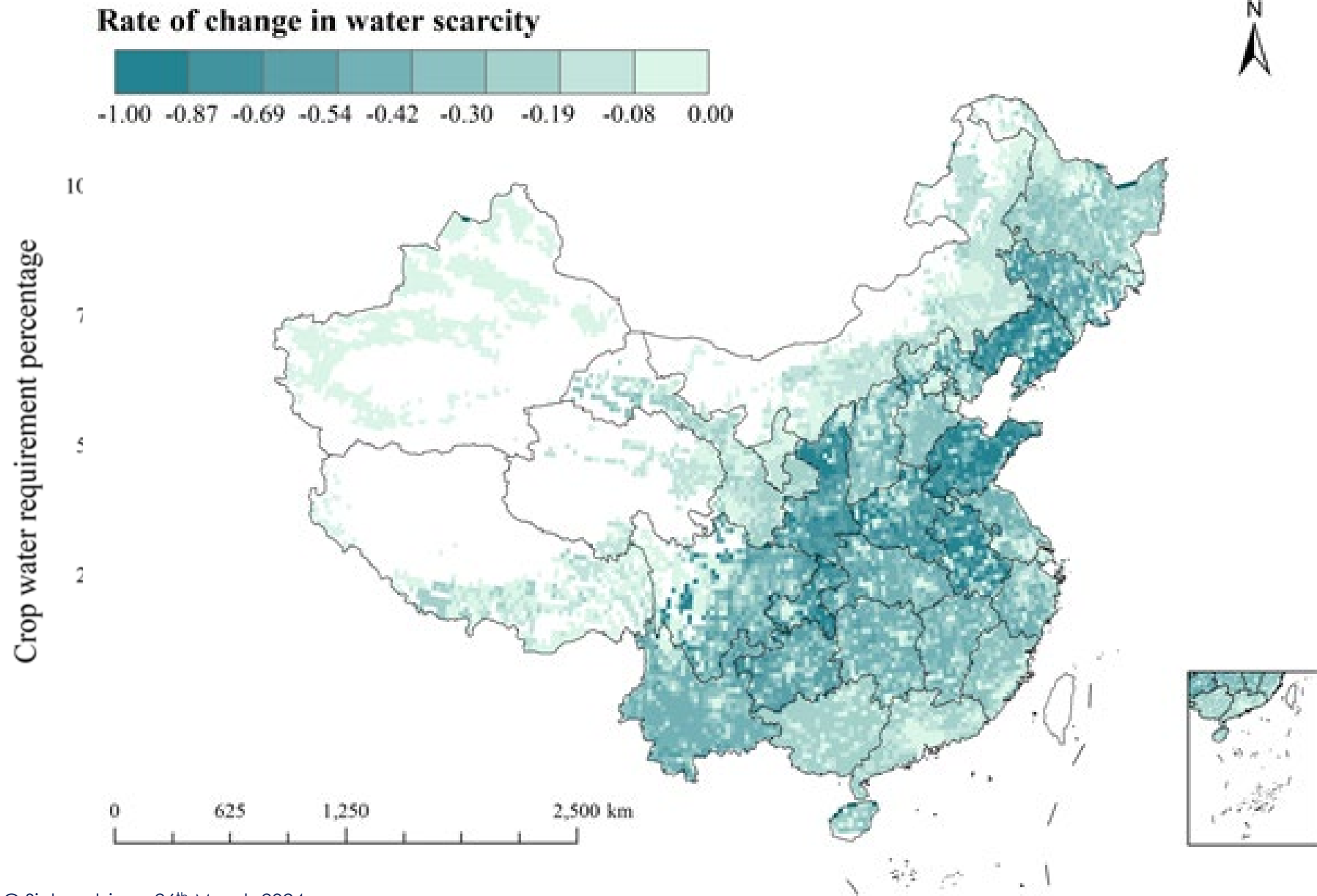
Biochar applications - soil



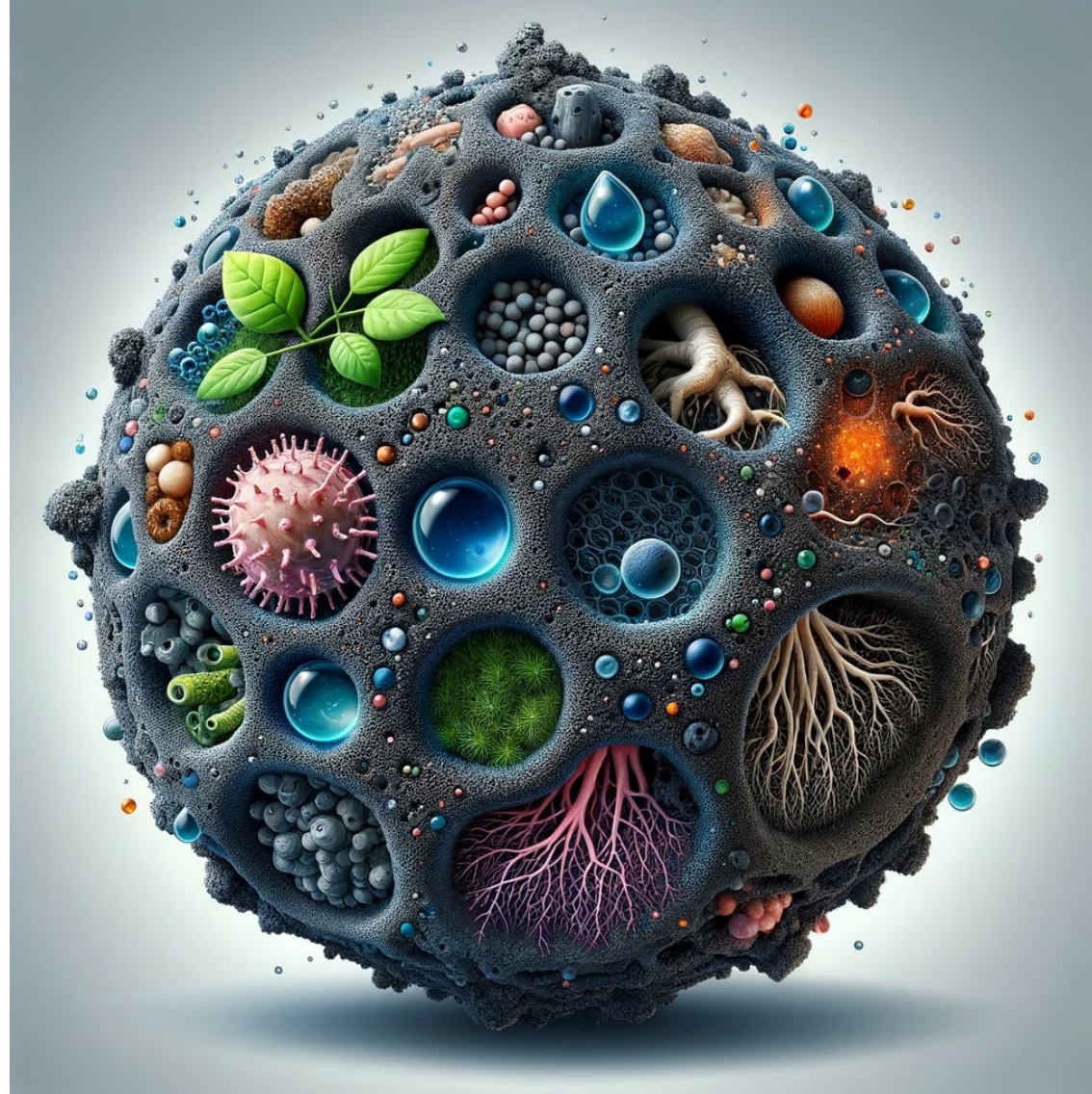
Biochar applications - soil



Biochar applications - soil



Biologically Enhanced Biochar





Biochar – polymer filler



Biodegradable mulch film



Biochar produced at UKBRC



©Novamont S.p.A.

Biochar-polymer composite masterbatch

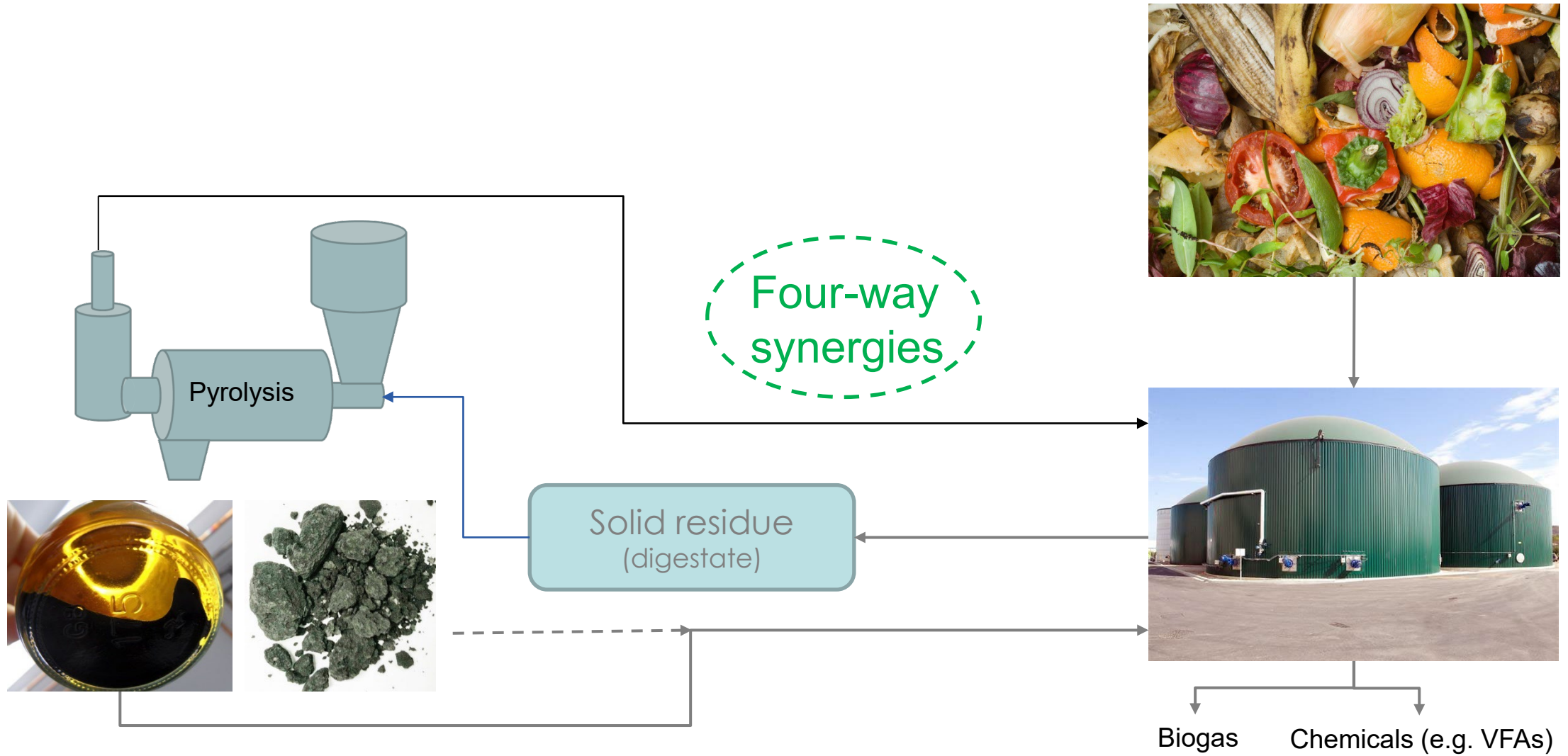


©Novamont S.p.A.

Biochar-polymer composite film blowing



Biochar – additive in AD



Biochar – additive in AD

First commercial products are emerging

Key benefits of integrating CreChar into your anaerobic digestion systems:



Enhanced Biogas Production by up to 10%+

Biochar provides a favourable habitat for beneficial microorganisms, resulting in increased biogas yields and improved methane production.



Enhance Quality of Biogas

Increased methane content by up to 3%.



Trace Elements

Improved microbial efficiency can lead to reduced requirements for trace element additions.

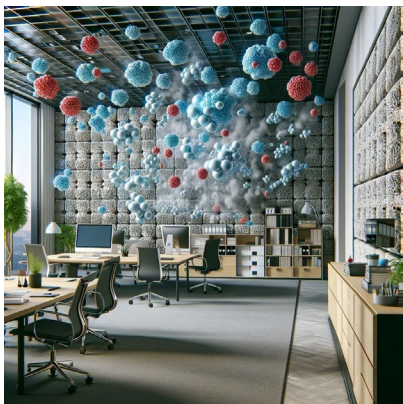


Reduced Process Instability

Biochar helps to reduce fluctuations and maintain stable process conditions, reducing the risk of process failure and downtime.



Biochar – use in urban environment



Indoor environment

Green roofs



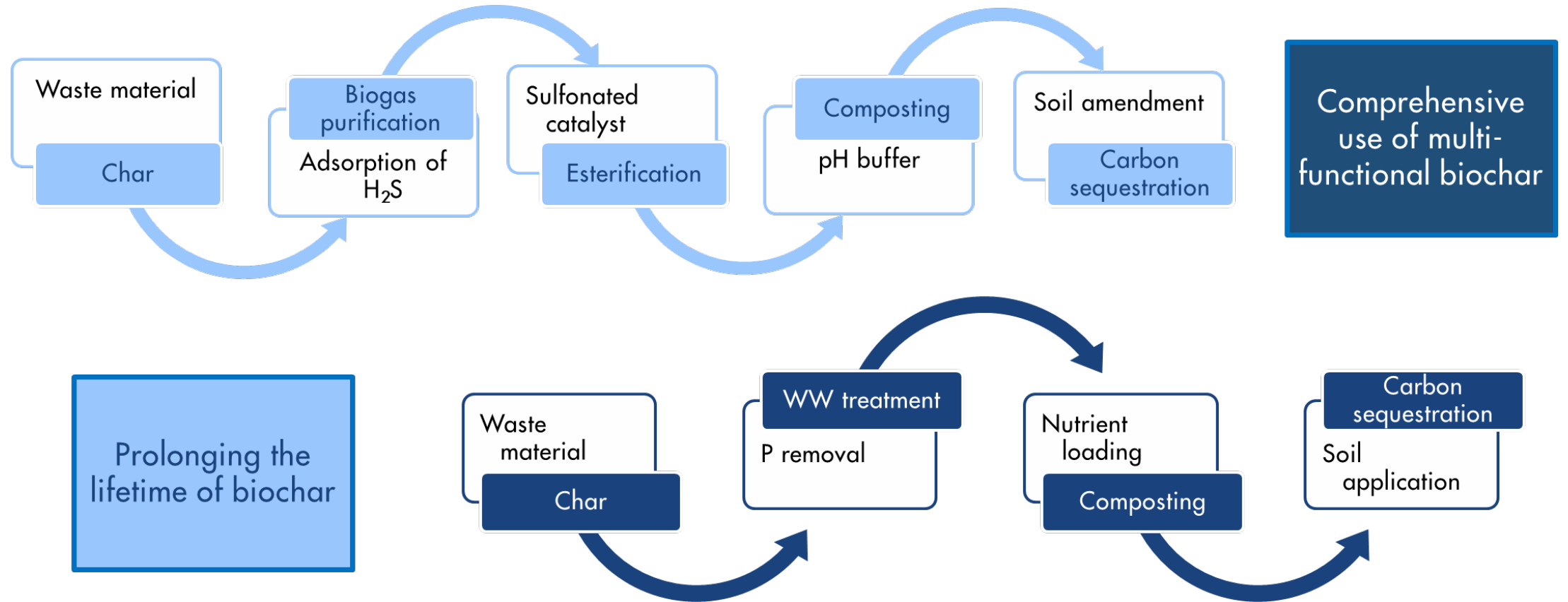
Building frames and facades

Roads and infrastructure





Biochar – sequential uses

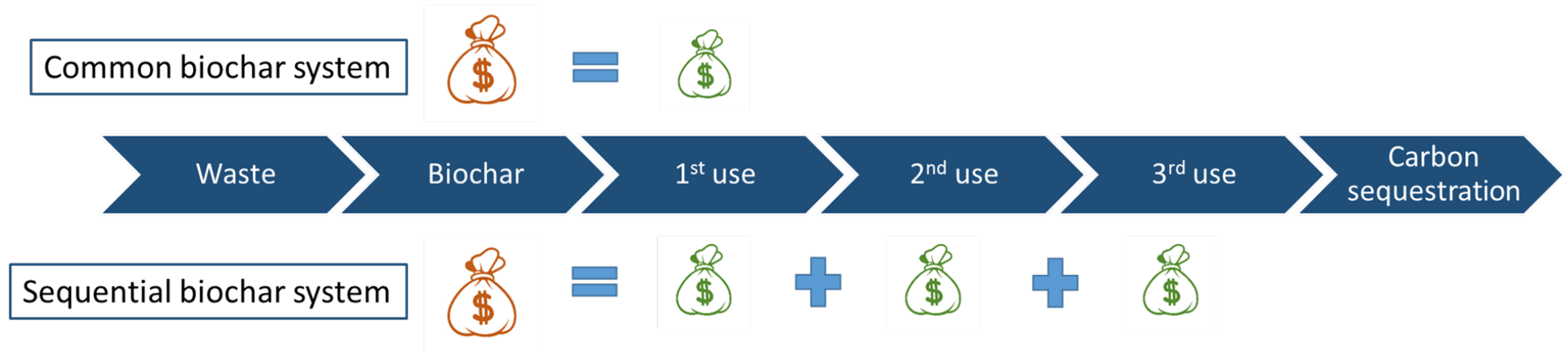


Source: Christian Wurzer



Biochar – sequential uses

Sequential biochar systems



Cost-division over several use phases

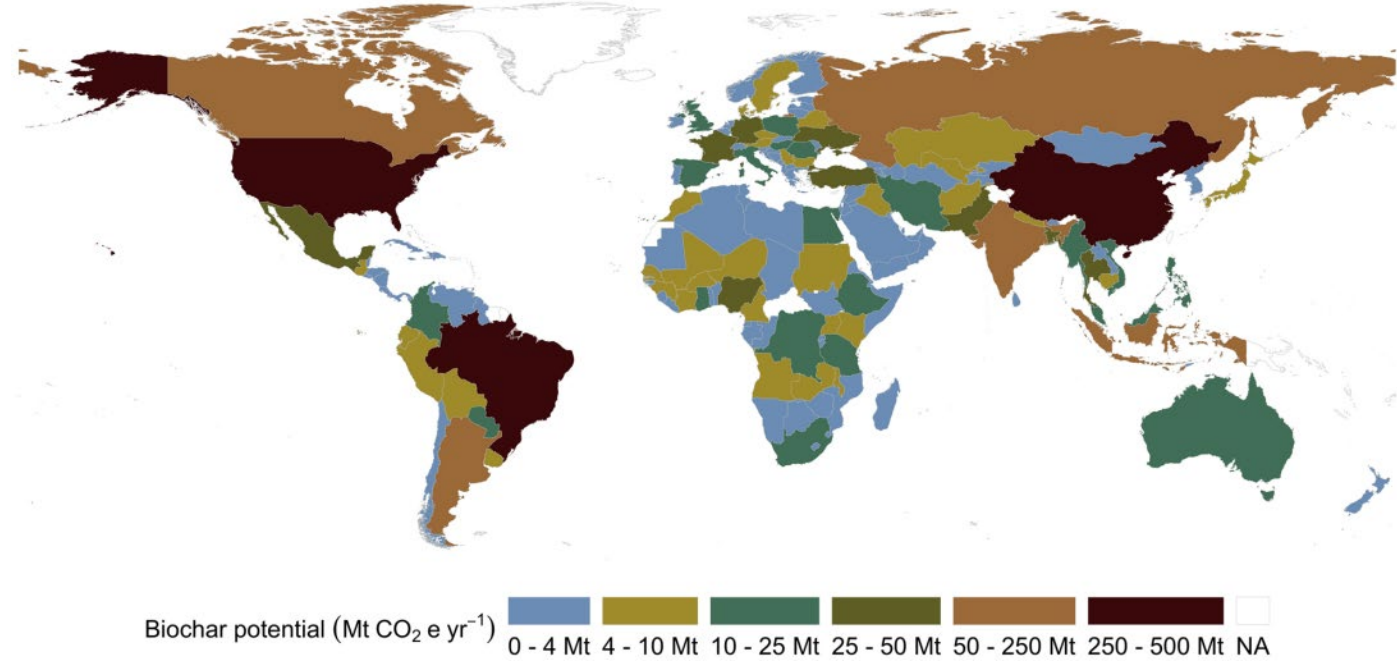
→ Carbon sequestration decoupled from carbon price



Biochar carbon removal potential

Biochar produced from agricultural residues, manure, and sludge

Biochar's carbon dioxide removal potential of $6.23 \pm 0.24\%$ of total GHG emissions in the 155 countries assessed



	Available biomass [Mio t yr-1]	Biochar potential [Mio t yr-1]	CO ₂ potential [Mio t yr-1]
UK	32.5	9.6	14.5

Lefebvre et al. 2023. <https://doi.org/10.1007/s42773-023-00258-2>

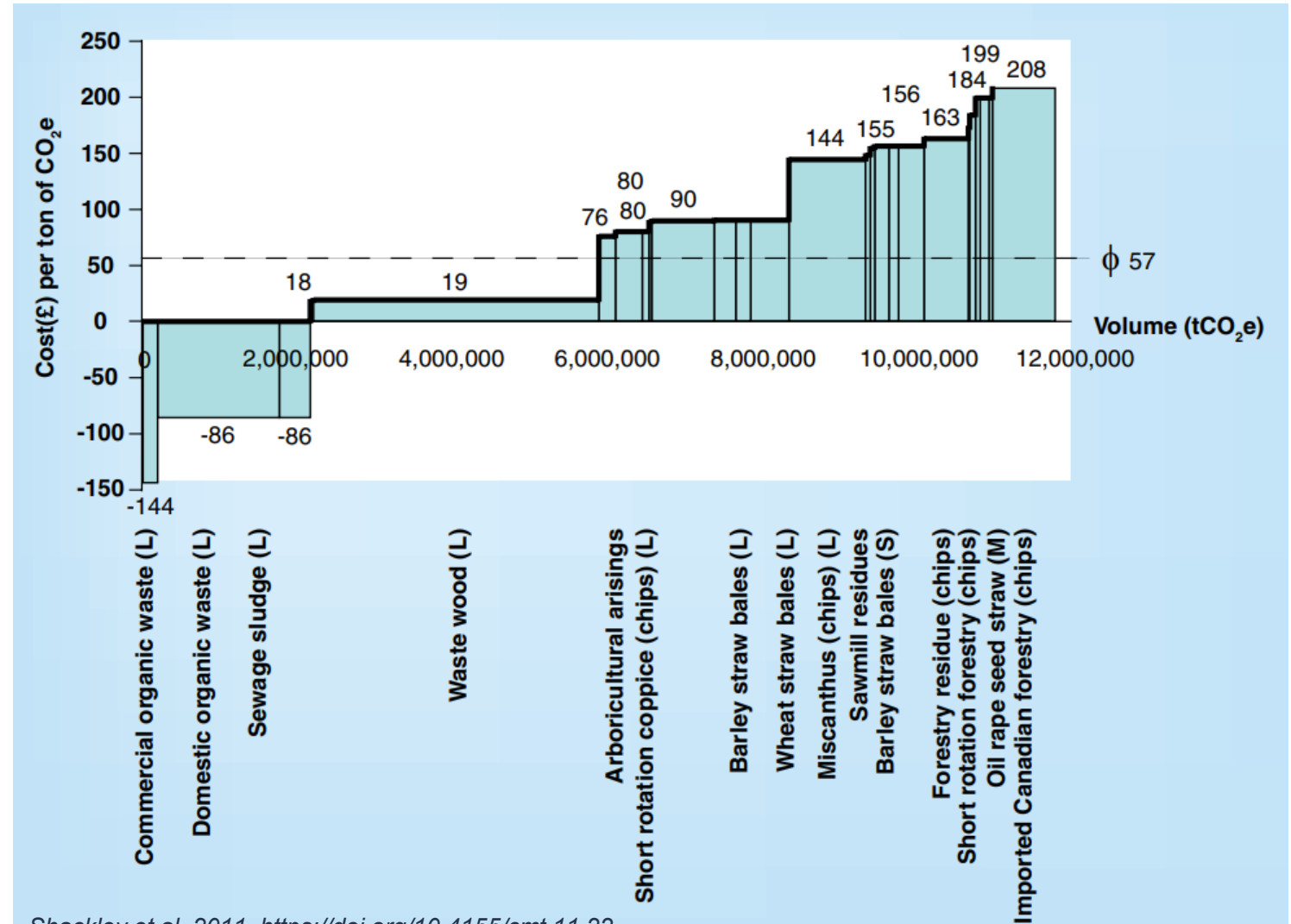




What does it cost?

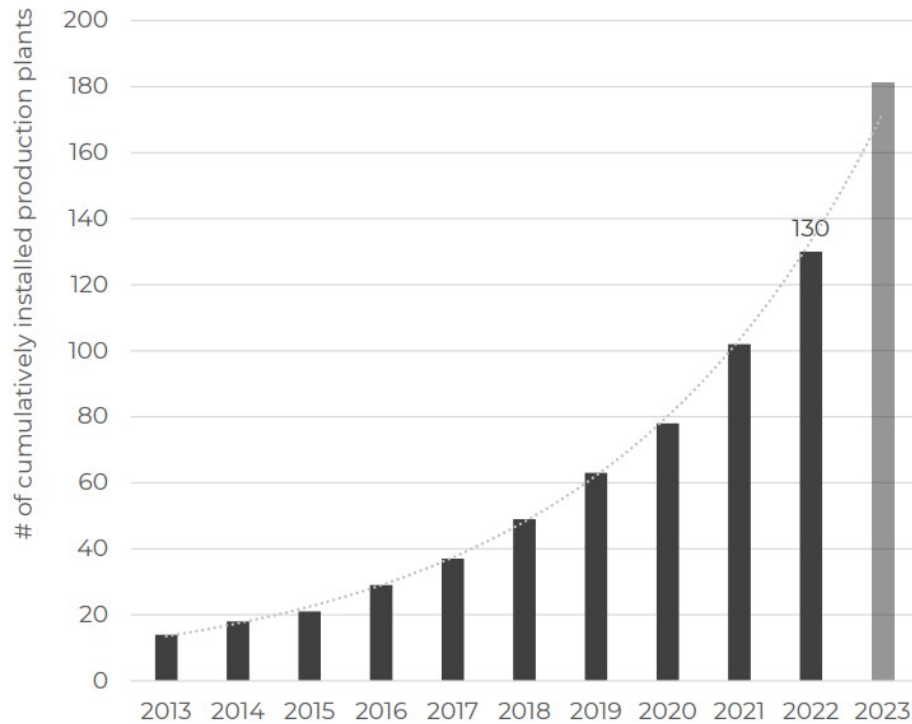
- CO₂ abatement costs are dependent on feedstock price
- Regulatory framework for biochar application must be in place
- EU fertiliser regulation enables wide application in agriculture since 2022 [UK equivalent missing]

Estimated CO₂ abatement costs for biochar in the UK



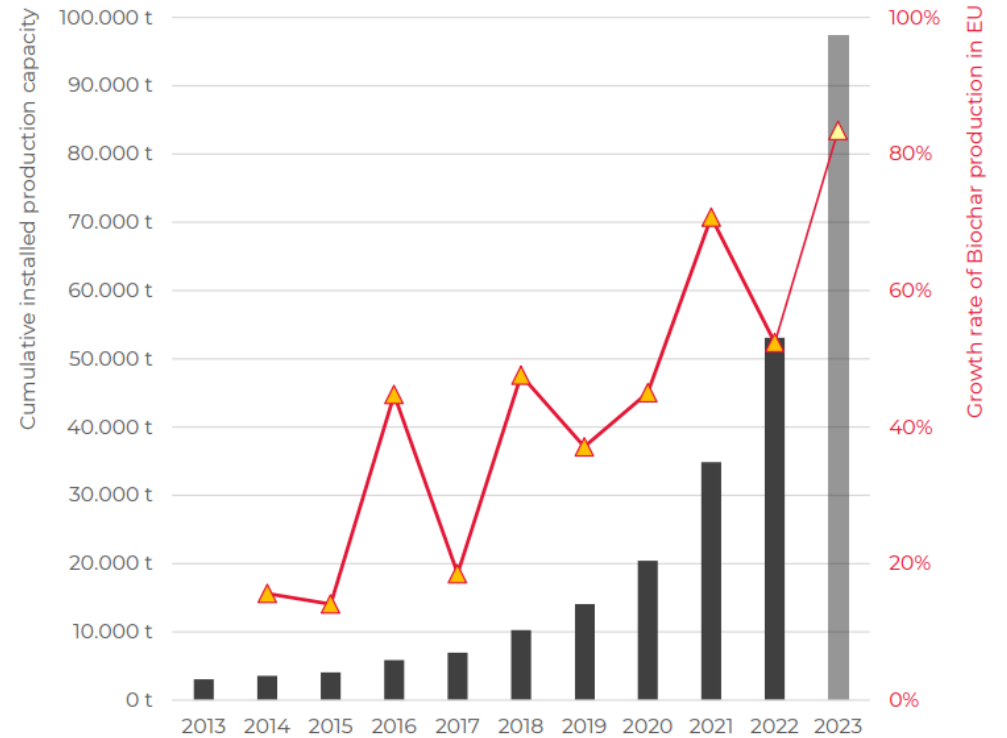
The biochar market

- The market is growing at annual growth rates of +50% [by volume]
- +130 production plants currently in operation in the EU



www.biochar-industry.com/market-overview/ © EBI 2023

Operational production plants [EU]



www.biochar-industry.com/market-overview/ © EBI 2023

Production capacity [EU]



Biochar carbon removal certificate market

- Biochar is the main technology **delivering** permanent carbon dioxide removal to date
- 9 out of top 10 CDR suppliers
- Current CO₂ certificate price at ~£115 per ton

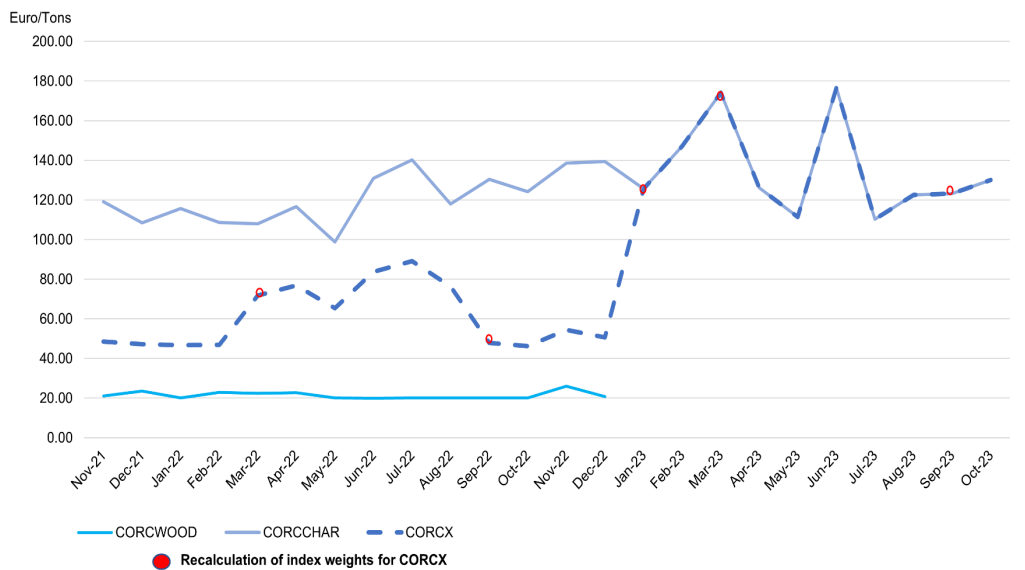
CDR.fyi Top 10 Carbon Removal Suppliers

Ranked by tonnes of CDR delivered

Name	Method	Total Sales
1 Wakefield Biochar	Biochar	25,170
2 Douglas County Forest Products	Biochar	11,403
3 Aperam BioEnergia	Biochar	7,300
4 Freres Biochar	Biochar	7,193
5 Charm Industrial	Biooil	6,416
6 Oregon Biochar Solutions	Biochar	5,689
7 Carbofex	Biochar	3,976
8 GreenSand	Enhanced Weathering	2,383
9 NovoCarbo	Biochar	2,209
10 Carbon Cycle	Biochar	1,782

<https://carboncredits.com/carbon-dioxide-removals-cdr-purchases-jump-437-in-first-half-of-2023/>

CO2 Removal Certificate Weighted Index Family (CORCX)



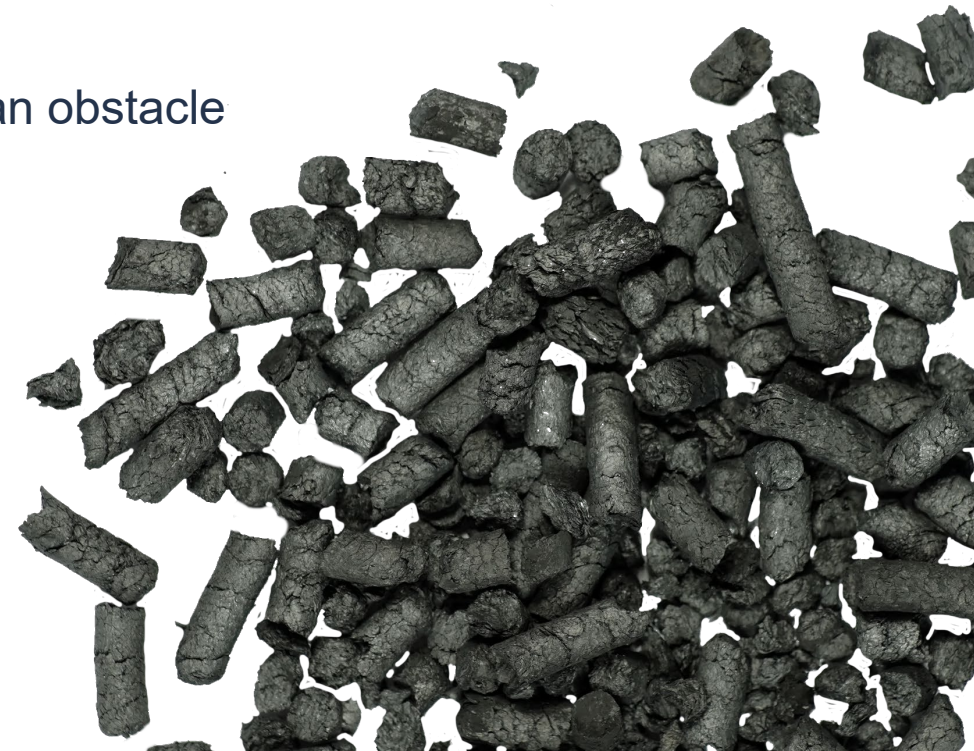
<https://www.nasdaq.com/solutions/carbon-removal-platform> [27.11.2023]



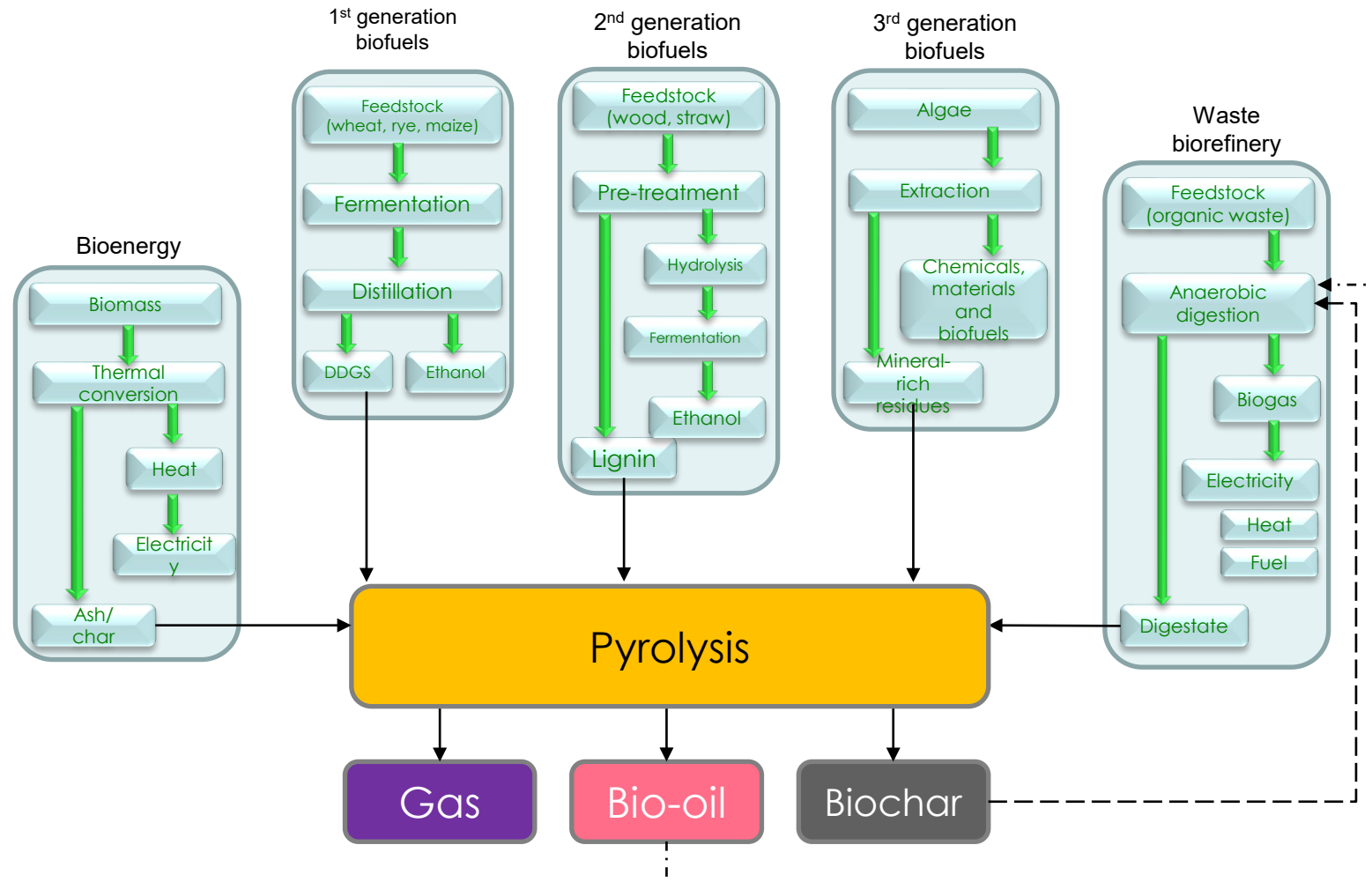


Biochar carbon removal

- Biochar is already commercially deployed (TRL9)
- Carbon negative material production
- Co-production of heat or electricity
- +130 European producers currently active
- Current CO₂ credit price of ~ £ 115 t⁻¹
- The regulatory framework and lack of standards is still an obstacle



Pyrolysis integration options in bio-energy systems





Thank you!



Prof. Ondřej Mašek
(Chair of Net Zero Emission Technologies)

Tel. +44 797 5682248

Skype: [ondrej.masek-ukbrc](https://www.skype.com/people/ondrej.masek-ukbrc)

Email: ondrej.masek@ed.ac.uk

Web: <http://www.geos.ed.ac.uk/homes/omasek>

Web: www.biochar.ac.uk



QR code: contact details

