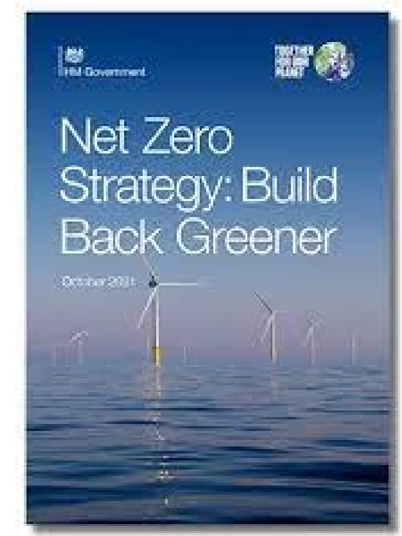
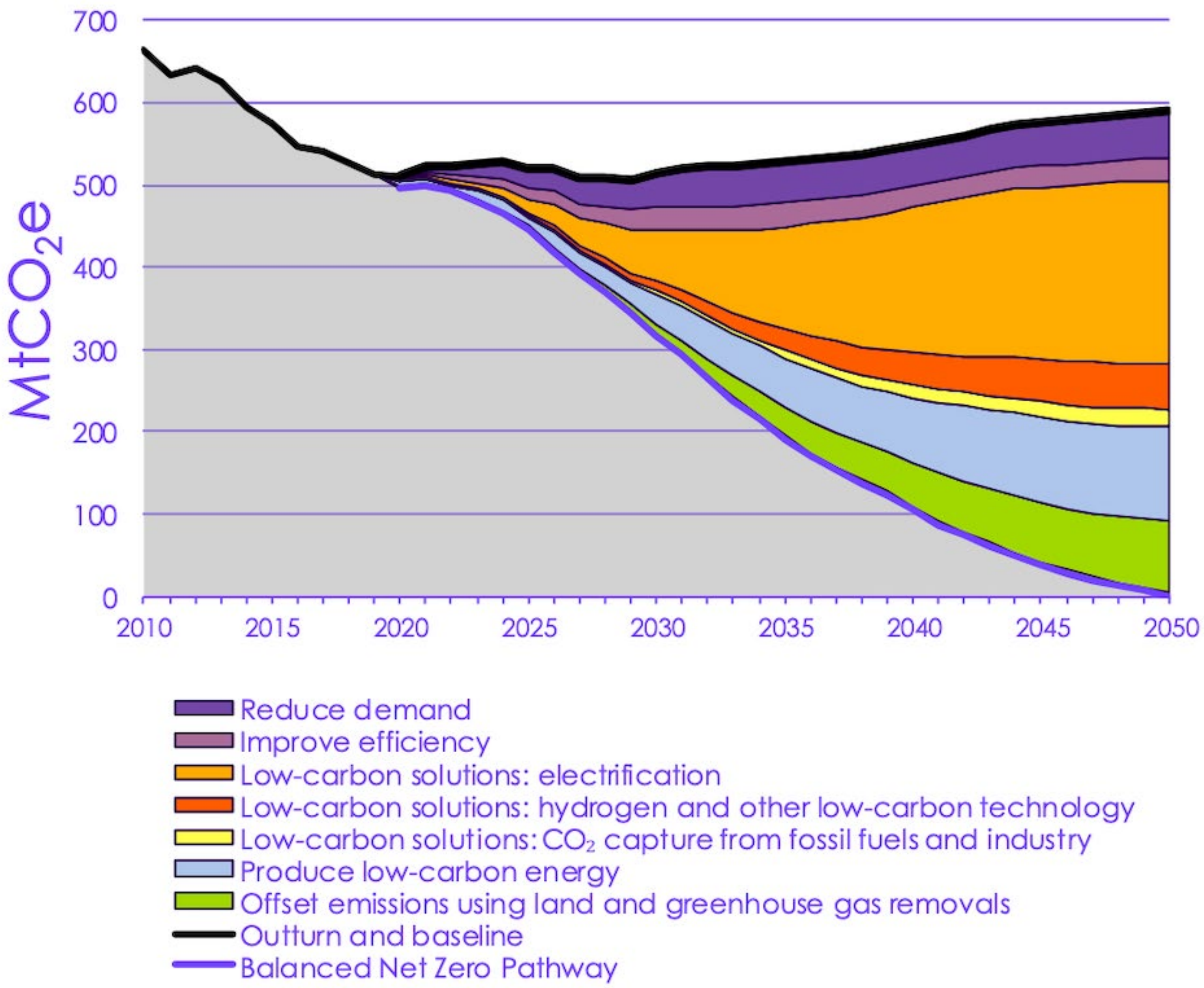
Biochar: its role in achieving net zero and treating wastes

Colin Snape
Colin.snape@nottingham.ac.uk



- The need for greenhouse gas removal (GGR), also referred to as CO_2 Removal (CDR) and Negative Emissions Technologies for the UK to achieve net zero by 2050.
- Why biochar and where does it sit in the portfolio or engineered and natural approaches for GGR?
- How can we ensure biochar deployed in arable settings and aggregates will be stable over millennia timescales?
- How can biochar add value to compost for treating wastes?

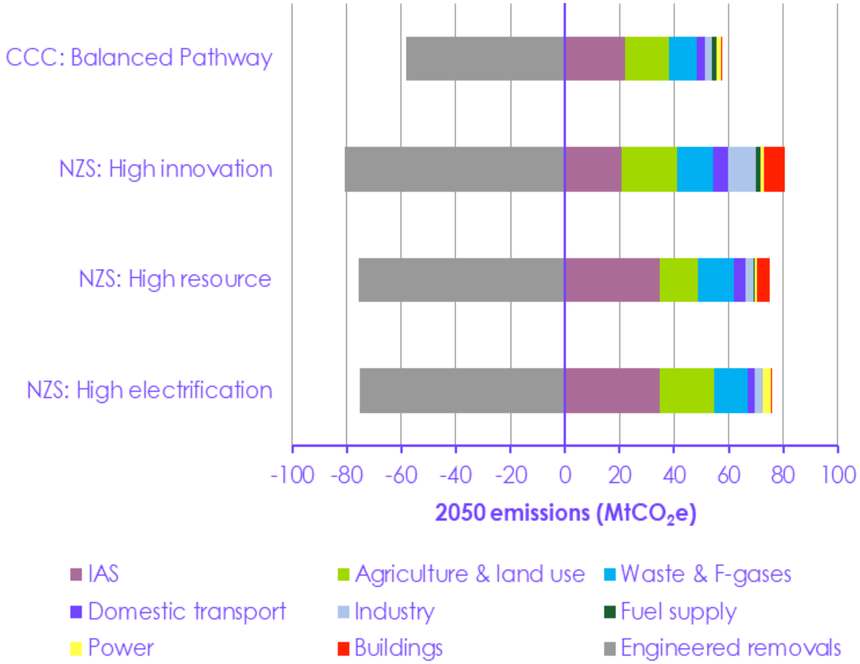
UK's overall pathway to 2050 Net Zero



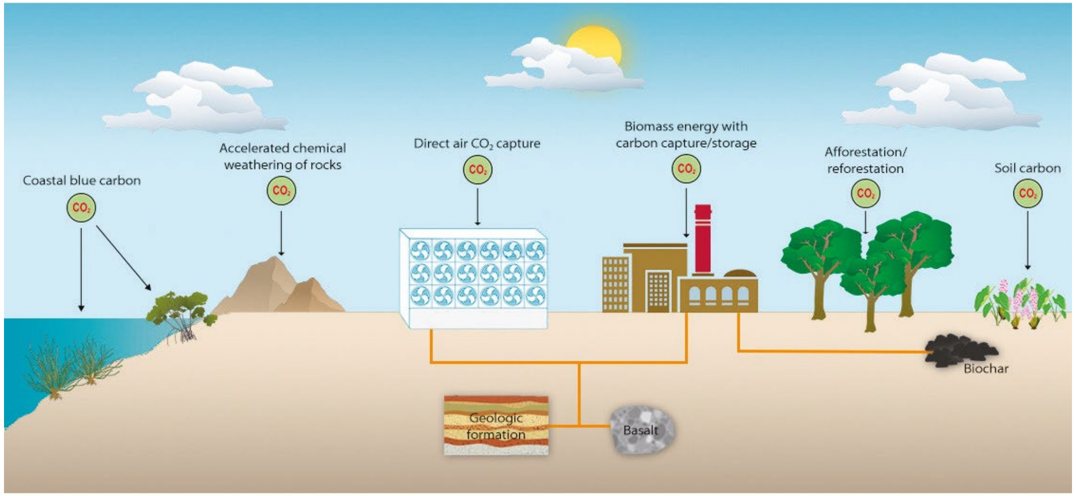
- Electrification dominates progress to date.
- Large future contribution from more electrification.
- Contributions from CCS, demand reduction, hydrogen.
- GGR - 15% of current emissions.

The Need for GGR Technologies by 2050 and Approaches Available

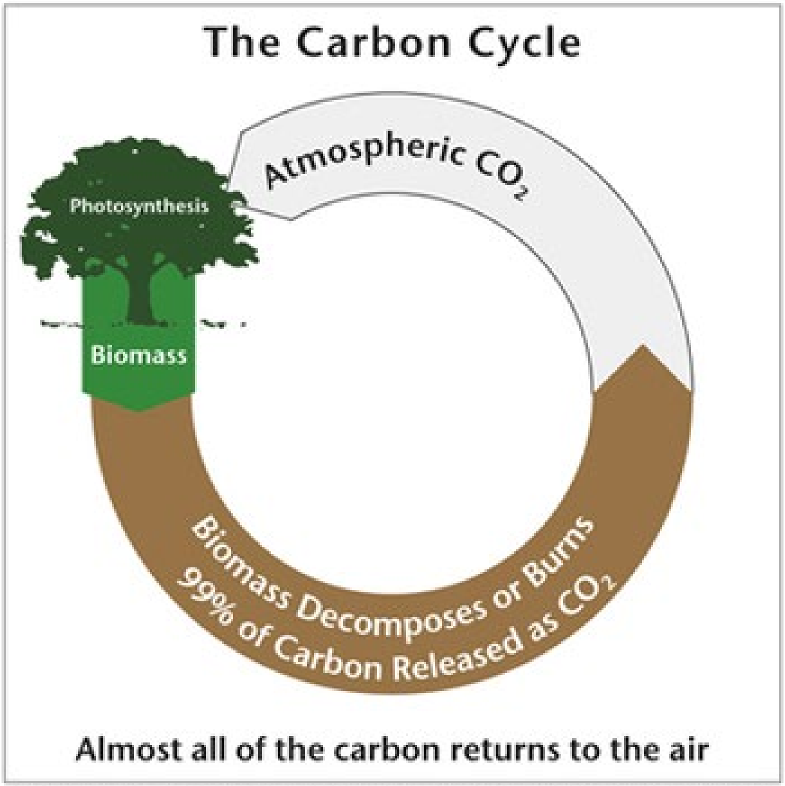
- deal with *ca*. 10-15% of current GG emissions



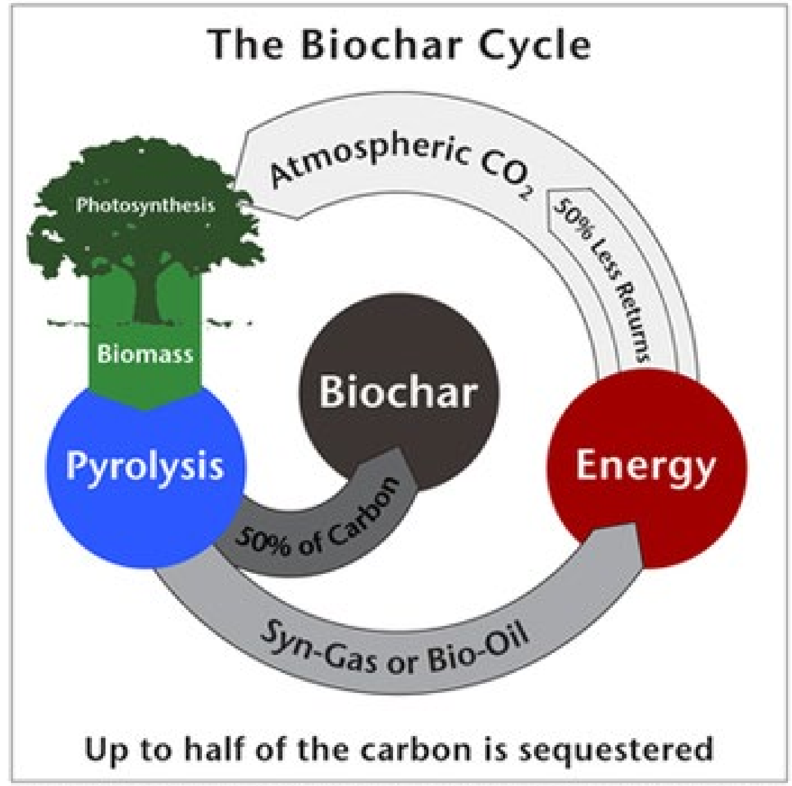
Source: CCC (2020) The Sixth Carbon Budget; BEIS (2021) Net Zero Strategy: Build Back Greener.
Notes: Global warming potentials from IPCC AR5 with feedback are used. Sectors are as defined in the Government's Net Zero Strategy.



How Biochar Removes Carbon



Green plants remove CO_2 from the atmophere via photosynthesis and convert it into biomass. Virtually all of that carbon is returned to the atmosphere when plants die and decay, or immediately if the biomass is burned as a renewable substitute for fossil fuels.



Green plants remove CO_2 from the atmophere via photosynthesis and convert it into biomass. Up to half of that carbon is removed and sequestered as biochar, while the other half is converted to renewable energy co-products before being returned to the atmosphere.

Biochar – what is it, how is it produced and what are the benefits?

Biochar

- Biochar is charcoal-like, produced by heating residues from agriculture, forestry and other sources in the absence of oxygen (pyrolysis, carbonisation) to make it carbon-rich and chemically-stable.
- Production generates surplus heat and power for export, scale is typically 500-3,000 tonnes per annum.

Benefits to agriculture – a "soil improver"

- Reduced leaching of nitrogen into ground water
- Possible reduced emissions of nitrous oxide
- Increased cation-exchange capacity resulting in improved soil fertility
- Moderate soil acidity
- Increased water retention
- Increased number of beneficial soil microbes.
- Reduced fertiliser use.

Areas with low rainfall or nutrient-poor soils, particularly sandy soils will most likely see the largest impact from addition of biochar.

What makes 'good' biochar?

Carbon Stability & Permanence

No risk of Environmental Harm

	EBC-Feed	EBC-AgroOrganic		Material
Pb	10 $g\,t^{-1}$ (88% DM)	45 $g\,t^{-1}$ DM		250 $g\,t^{-1}$ DM
Cd	0.8 $g\,t^{-1}$ (88% DM)	0.7 $g\,t^{-1}$ DM		5 $g\,t^{-1}$ DM
Cu	70 $g\,t^{-1}$ DM	70 $g\,t^{-1}$ DM		250 $g\,t^{-1}$ DM
Ni	25g t^{-1} DM	25 $g\,t^{-1}$ DM	50 $g\,t^{-1}$ DM	250 $g\,t^{-1}$ DM
Hg	0.1 $g\,t^{-1}$ (88% DM)	0.4 $g\,t^{-1}$ DM	1 $g\,t^{-1}$ DM	1
Zn	200 $g\,t^{-1}$ DM	200 $g\,t^{-1}$ DM	400 $g\,t^{-1}$ DM	
Cr	70 $g\,t^{-1}$ DM	70 $g\,t^{-1}$ DM	90 $g\,t^{-1}$ DM	
	88% DM)	13 $g\,t^{-1}$ DM	13 $g\,t^{-1}$ DM	

Physical Properties

Particle Size

Porosity

The UKRI GGR Programme

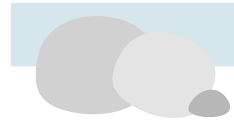
GGR Demonstrators

- £4.5 million investment per Demonstrator
- Funded for 4.5 years from May 2021
- Explore effectiveness, cost and the limitations of large-scale methods of GGR. Including environmental impacts and key economic, financial, ethical, legal, social, cultural, behavioural and governance issues
- Moving towards TRL 3-4 (or greater)
- Flexible fund for business engagement
- Cross programme engagement with the Directorate Hub, other Demonstrators and the national and international GGR community

CO2RE hub

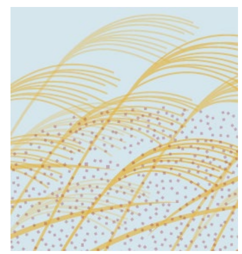
Directorate Hub (Cameron Hepburn, University of Oxford)

- Cross programme co-ordination
- Connecting to other relevant GGR programmes (e.g. BEIS GGR programme)
- Cross cutting research
- Commissioning research (flexible funding)

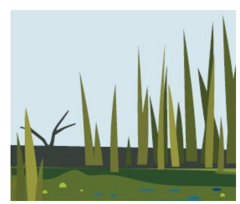


Enhanced Rock Weathering (David Beerling, University of Sheffield)
Amending soils with crushed silicate rocks as a GHG removal technology

Afforestation (Ian Bateman, University of Exeter)
Gathering evidence, addressing knowledge gaps and allowing decision makers to explore the GGR consequences of different tree planting options to identify "the right tree in the right place"



Perennial biomass crops (Iain Donnision, IBERS, Aberystwyth University)
Addressing the barriers to the rapid scale-up of the perennial bioenergy crops, *Miscanthus* and short rotation coppice willow to support the implementation of bioenergy with carbon capture and storage (BECCS) in the UK



Peatland rehabilitation (Chris Evans, UK CEH)
Re-creating and, where possible enhancing, the environmental conditions that lead to peat formation to re-establish a secure long-term carbon store in the landscape that has been lost due to drainage

Biochar (Colin Snape, University of Nottingham)
Addressing the uncertainties concerning the extent and scope of deployment of biochar

UK Research and Innovation

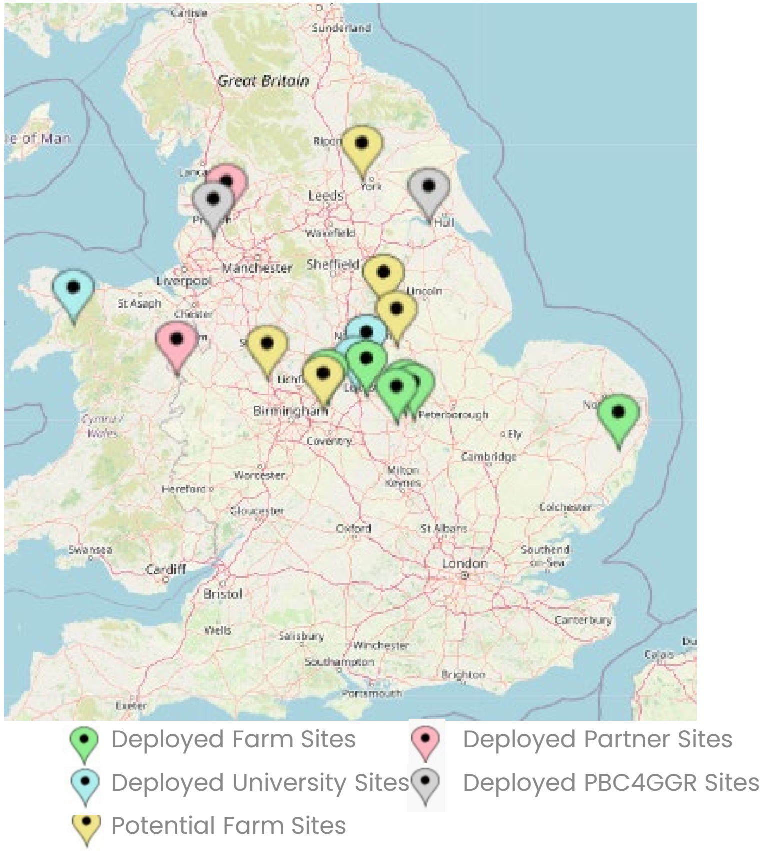
- ***Plus £60M from BEIS for developing GGRs, including engineered approaches - 5 biochar projects.***

Demonstrator Programme Overview

- **> 200 tonnes of biochar to be deployed**
- **understand agronomic and ecosystem service impacts**
- **identify agricultural co-benefits**
- **Integrated techno-economic and life cycle analysis**
- **Extensive stakeholder engagement**

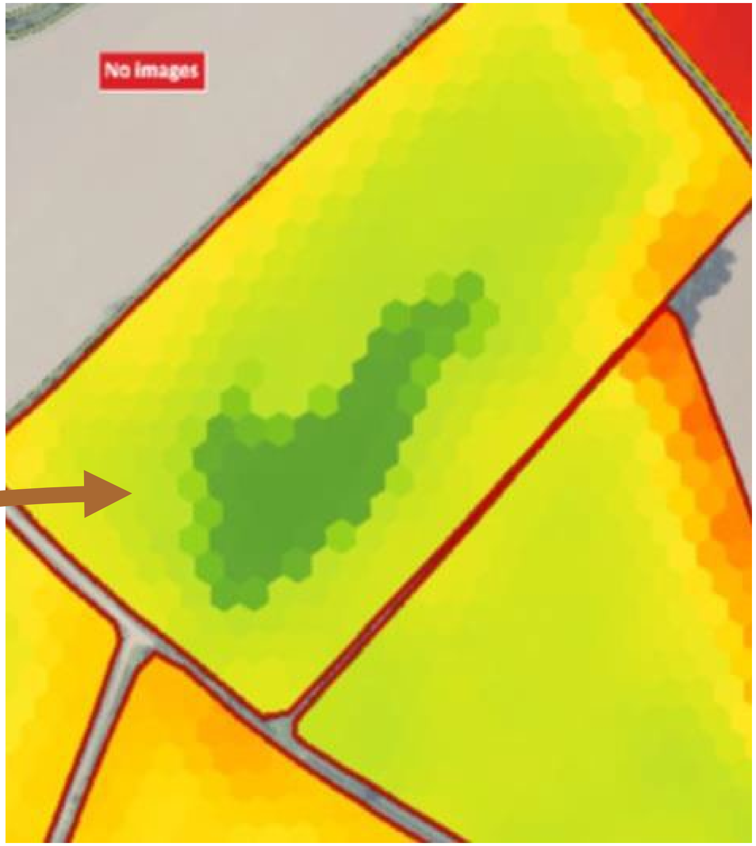
Our trials
- arable land, forestry and grassland

- 10 t/ha
- Ploughed, surface spread or buried
- With and without amendments
- No changes to field treatment
- 5+ year monitoring

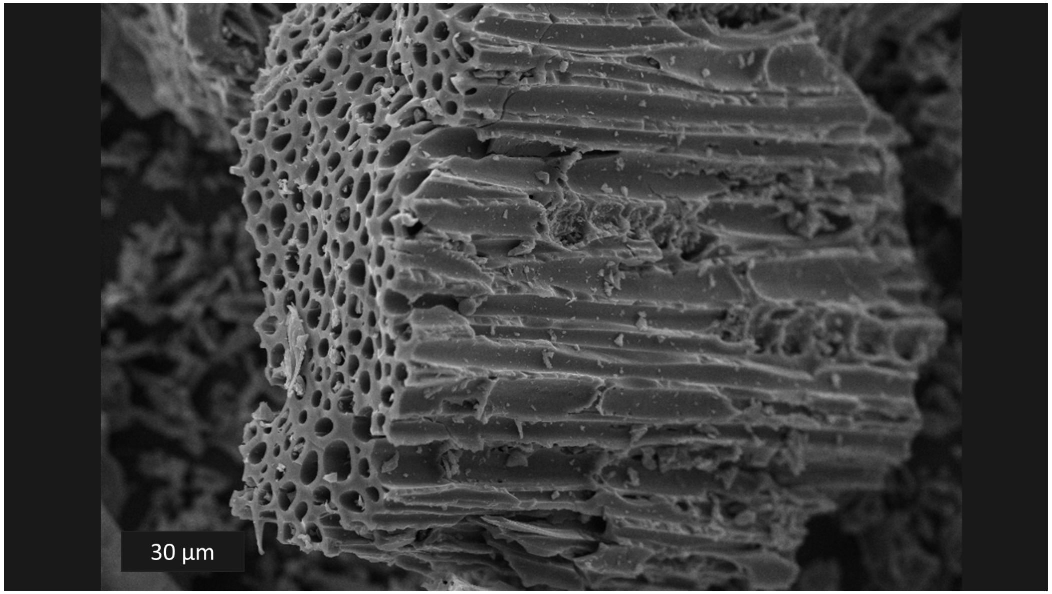


Results so far…

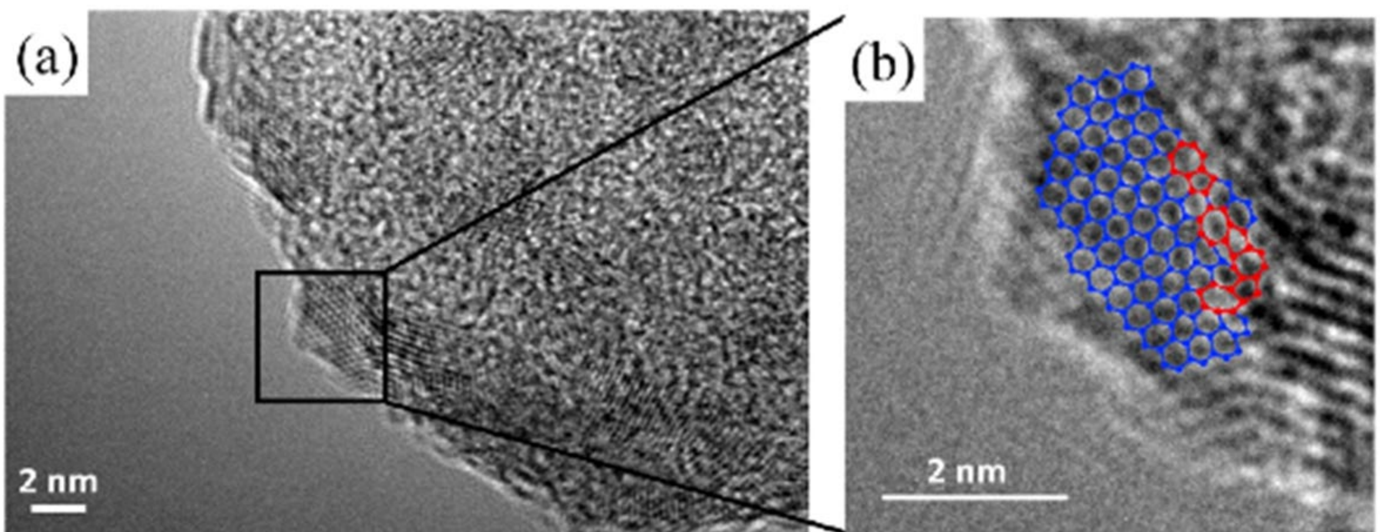
- **No negative impacts** of biochar deployment at 10 t/ha
  - Across all sites
- Site specific positives
  - Yield & Leaf area index
  - GHG emissions
  - Earthworms, biodiversity



Biochar – Scanning and transmission EM images



- Biochar is extremely porous – high macropore volume.
- TEM indicates large aromatic clusters.

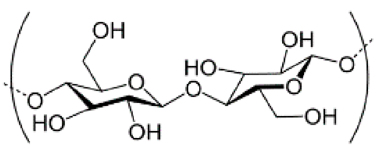


Xiao and Chen 2017 DOI: 10.1021/acs.est.6b06300

Long-term Carbon Stability

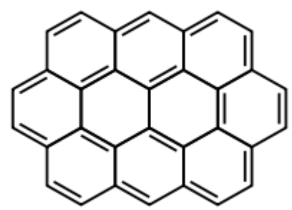
- How persistent is biochar?
- How does this relate to the aromatic structure?
- High stability necessary to obtain maximum payments in C trading.

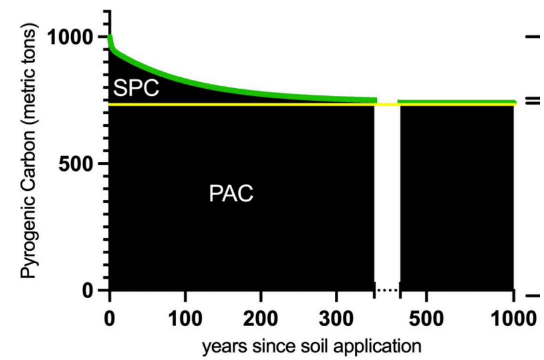
Biochar composition determines its longevity in soil (stability)



Non-aromatic
Labile Carbon Fraction
Degrades over short timescales

Polyaromatic (SPAC)
Stable Carbon Fraction
Stable over long timescales





- Stable or persistent carbon – SPAC/PAC can be determined by HyPy.
- Ongoing collaboration with Ithaka Institute (leading European biochar research foundation).
- ^{14}C measurement of evolved CO_2 incubation experiments to measure actual rate of biochar mineralisation (using ^{14}C-dead char).

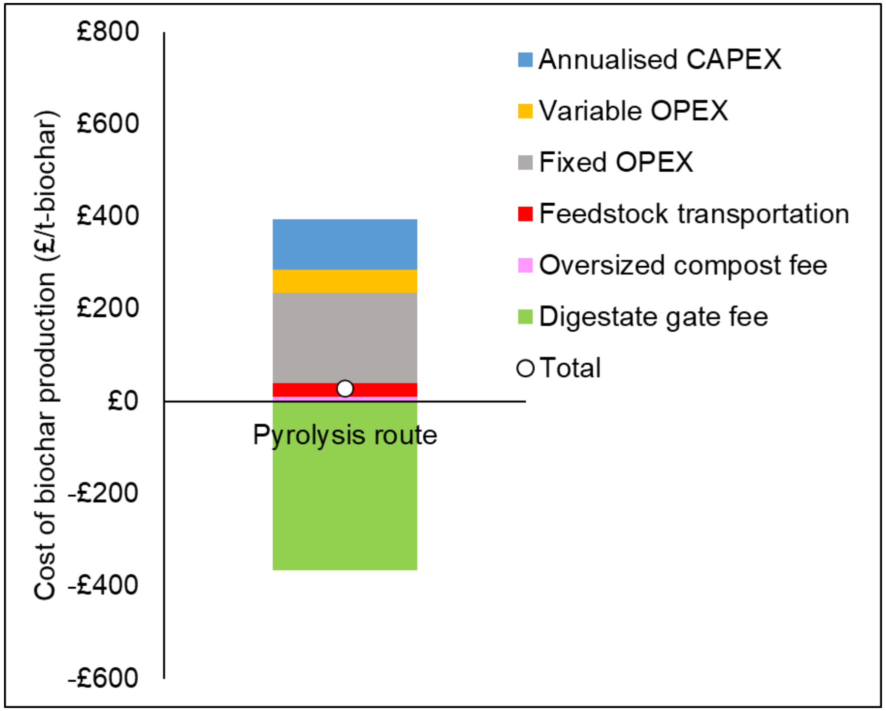
BEIS GGR Innovation Project
Bio-waste to biochar (B to B)

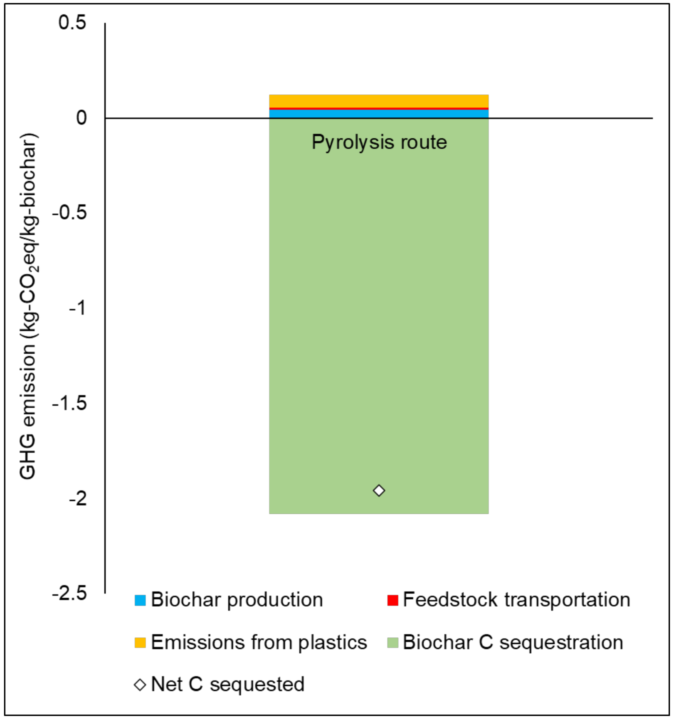
B to B **using AD fibre** = drying + High temperature pyrolysis

- AD of food waste by 2030 will represent >1Mt of CO_2 equivalent but, typically contains 5-10% plastics.
- Over 50 tonnes of AD fibre processed to optimise HTC plant for Phase 2, fully integrated with HTT.
- Very stable biochar obtained at *ca*. 700°C, with atomic H/C ratio <0.5 and stable polyaromatic carbon content of over 90%, satisfying voluntary EBC standard.
- LCA and economics demonstrate cost per tonne of CO_2 avoided is ca. _£20 even without C credits.
- Demonstration plant operational, can produce 2,000 tonnes of biochar p.a.

"End to end" solution to a major environmental problem for AD industry.

Bio-waste to biochar
– example of techno-economic and life cycle analysis for plastic containing digestate.





- Example is for 70% food AD fibre and 30% over-sized compost.
- Vast reduction in gate fee compared to incineration/land fill.
- Plant operating with 10,000 tonnes p.a. (dry feedstock basis) can nearly breakeven before income from carbon trading is considered, *ca*. £300 per tonne of biochar produced.

Biochar Commercial Developments
- 2023 global market of 350,000 tonnes, $600M

University of Nottingham
UK | CHINA | MALAYSIA

- Biochar production is happening, already at TRL9
  - Several plants in the UK include that operated by Invica Industries (DESNZ Phase 2 GGR project),Woodtek and Pyreg.
- Deployment in agriculture and aggregates.
  - Niche markets – animal feed and horticulture
  - Add to compost and digest, also aids composting and AD.
- Commercial plants are being established through joint ventures
  - favourable to minimise risk for councils and non-processing industry.
- Large emitters, including big data companies are investing directly in GGR rather than buying credits through carbon trading platforms.
- Biochar represents a solution for plastic-containing digestate.
- Needs to be scaled up rapidly to address the 2050 GGR target.

Biochar
DEMONSTRATOR

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