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Initial Life Cycle Analysis for Pyrolysis Biochar Systems in the UK

Hammond, J[a]*; Shackley, S[a]; Sohi, S[a]; Brownsort, P[a]
[a]UK Biochar Research Centre, University of Edinburgh, Crew Building, King's Buildings, Edinburgh, EH9 3JN, United Kingdom.
*E-mail: Jim.Hammond@ed.ac.uk

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Introduction

A life cycle assessment (LCA) was undertaken of slow pyrolysis biochar systems (PBS) in the UK context. Configurations using small, medium and large scale pyrolysis units and distributed or centralized process chains were analysed for eleven likely UK feedstocks, including: short rotation coppice, miscanthus, short rotation forestry, straws, forestry, and forestry residues. Biochar was assumed to be incorporated into mainstream UK arable farmlands. Carbon abatement (CA) and electricity production were monitored. Results were compared to equivalent biomass combustion, fast pyrolysis and gasification.

The LCA technique was attributional rather than consequential [1]; meaning that only those effects directly attributed to actions within the system were included. Land use change emissions or market effects due to re-allocation of resources were not included, with the exception of energy export form pyrolysis offsetting fossil fuel emissions. Data on UK specific logistics and feedstocks were taken from well established research efforts [2,3], pyrolysis data from comprehensive literature survey [4], and biochar stability and biochar-soil interactions from literature survey and expert elicitations [5].

Results and Discussions

Pyrolysis biochar systems appear to offer greater carbon abatement than other bioenergy systems available at present. Carbon abatement of 0.71–1.24 tCO_2e per oven dry tonne (odt) of feedstock processed was found. Expressed in terms of delivered energy PBS abates 1.4–1.8 tCO_2e/MWh, which compares to average carbon emissions of 0.05–0.30 tCO_2e/MWh for other bioenergy systems. Assuming that biomass is replanted after harvesting, PBS can therefore be said to deliver carbon negative energy. Expressed in terms of land-use, PBS appears to abate approximately 5.4–21.5 tCO_2e/ha compared with typical bioenergy carbon abatement of 1–7 tCO_2e/ha. Although larger scale PBS with more centralised supply chains delivered higher net carbon abatement and more useful energy, smaller and more distributed systems appear to be also very much worth pursuing.

Table 1. Carbon abatement efficiencies and electricity production for small, medium and large scale pyrolysis biochar systems.

	Small	Medium	Large
Carbon Abatement			
tCO_2e/odt feedstock	0.71	1.12	1.12
tCO_2e/MWh electricity	2.38	1.61	1.40
tCO_2e/ha	12.46	11.2	6.65
tCO_2e/t char	2.15	3.38	3.39
Total tCO_2e/yr per facility	1068	16802	84248
Electricity Production			
Electrical efficiency (%)	6	15	16
MWh/odt feedstock	0.3	0.7	0.8
MWh/ha	5.25	6.96	4.76
Total MWh/yr per facility	450	10447	60366

Three feedstock availability scenarios were created – low, medium and high – for UK by 2020. From these, total carbon abatement of 3.6–11.1 $MtCO_2e$ per year could be achieved [6].

The largest contribution to PBS carbon abatement (40–50%) is from the feedstock carbon stabilised in biochar. The next largest contribution (25–40%) arises from the more uncertain effects of biochar upon the build-up of soil organic carbon levels. Change in soil organic carbon levels was found to be a key sensitivity. Electricity production off-setting emissions from fossil fuels accounts for 10-25% of carbon abatement. The LCA suggests that provided 43% of the carbon in biochar remains stable, PBS will out-perform direct combustion of biomass at 33% efficiency in terms of carbon abatement, even if there is no beneficial effect upon soil organic carbon levels from biochar application.

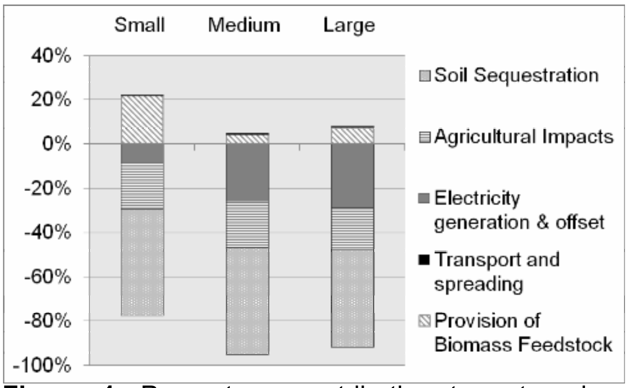

Figure 1. Percentage contribution to net carbon abatement by life cycle stage; for small, medium and large scale pyrolysis biochar systems.

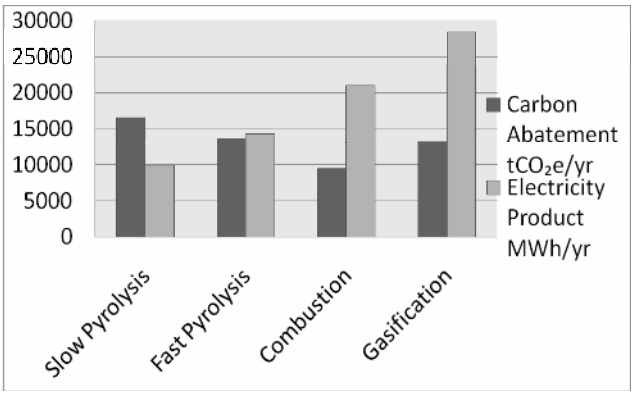

Figure 2. Carbon abatement and electricity produced from different ways of processing 20,000 tonnes of biomass.

The most important factor in determining overall carbon abatement was the amount of stable carbon in biochar entering the soil. Increased biochar yields whilst maintaining stable carbon content increased net carbon abatement, and biochar losses during transport or field application reduced net CA. The carbon stability factor of 0.68 was used, meaning that 68% of the carbon in the fresh biochar was assumed to remain after 100 years. Reduced carbon stability had a major effect upon net CA. This study assumed that biochar additions led to crop NPP increase of 10%, and increase in soil organic carbon levels by 21% (after 100 years). This soil organic carbon increase constituted a major (25–40%) contribution to net CA, but is perhaps the least well understood element of the biochar lifecycle. Improved conversion efficiency of biomass products to electricity or the use of low grade heat to offset fossil fuel use further benefited increased net carbon abatement. Transport distances and fertiliser offsets were found to be negligible in terms of carbon reductions.

Whilst PBS delivers energy in the form of syngas and bio-oils, the amount of energy delivered per unit of biomass processed was at least 50% lower than for other bioenergy systems, presenting a choice as to whether to use biomass for energy production or greater carbon abatement. In the UK low carbon electricity is rewarded where as carbon abatement is not, incentivising other uses of biomass than biochar. Even without incentives, electricity is a more marketable product than biochar at present. Until the agronomic effects of biochar can be predicted accurately, it may be difficult to market, and therefore justify any biochar production which does not offer substantial electricity production, at least in non-agricultural economies. Fast pyrolysis may present such a middle ground of biochar and energy production.

Conclusions

Pyrolysis biochar systems as assessed in UK conditions appear to offer greater carbon abatement than other bioenergy systems available at present. Carbon abatement of 0.71–1.24 $tCO_2e\ odt^{-1}$ of feedstock processed was found. Biochar carbon stability is a key determinate of how much carbon can be abated, and biochar effect on soil organic carbon stocks is potentially a very important uncertainty in biochar systems.

Biochar systems produce less electricity than other advanced bioenergy systems, which makes biochar less appealing to investors when electricity has a higher market value than carbon abatement. The agronomic benefits of biochar could help to add value, but are not yet predictable enough to be marketed.

[1] Brander M, Tipper R, Hutchison C, Davis G. Consequential and Attributional Approaches to LCA: a Guide to Policy Makers with Specific Reference to Greenhouse Gas LCA of Biofuels. Edinburgh, Ecometrica; 2008.
[2] Mortimer ND, Evans A, Shaw VL, Hunter AJ. Life Cycle and Techno-Economic Assessment of 1 the North East Biomass to Liquids Project. York, North Energy Associates Limited; 2009.
[3] Thornley P, Upham P, Tomei J. Sustainability Constraints on UK Bioenergy Development. Energy Policy 2009; 37(12):5623-35.
[4] Brownsort P. Biomass Pyrolysis Processes: Review of Scope, Control and Variability. Working Paper 5, Edinburgh, UKBRC. 2009
[5] Hammond J, Shackley S, Sohi S, Brownsort P. Predicted Life Cycle Carbon Abatement for Pyrolysis Biochar Systems in the UK. Forthcoming.
[6]Shackley S, Sohi S, (eds). An assessment of the benefits and issues associated with the application of biochar to soil. Edinburgh, UKBRC, Defra; 2010.