UKBRC

Biochar:

An Emerging Technology for Climate Change Mitigation?

Workshop proceedings, 1st April 2009

Saran Sohi, Simon Shackley, Mandy Meikle, Kimberley Pratt, Elisa Lopez-Capel, Stuart Haszeldine, John Gaunt, Ondrej Masek, and Sarah Carter

April 2009

UKBRC Working Paper 1:

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www.biochar.org.uk

Biochar: An Emerging Technology for Climate Change Mitigation?

1 April 2009, George Square, University of Edinburgh

Introduction: Biochar has emerged as a carbon mitigation option of potentially global significance. But many key questions remain to be addressed before we can be confident that biochar can be a major part of the move to a sustainable zero-carbon economy.

Aims of the Workshop:

- to map out the key research needs in establishing what role biochar may have in limiting atmospheric concentrations of CO_2 and other greenhouse gases;
- to identify the key research needs in deployment of biochar for carbon storage and as a soil amendment;
- to review and assess the role that the UK research community can and should have in addressing the above-identified research needs;
- to share information and to discuss how UK researchers can work together in meeting these research needs.

Contents

Programme

10.00 -10.55 am - Registration - Coffee/Tea on the balcony

Morning Chair: Professor David Manning, Newcastle University

11.00 -11.10 am – Welcome & Introduction – **Professor Stuart Haszeldine**, Scottish Centre for Carbon Storage, University of Edinburgh

11.15 – 11.45 am – **Keynote Presentation** - **The Biochar Landscape, Dr John Gaunt** Adjunct Associate Professor, College of Agriculture and Life Sciences, Cornell University

11.50 – 12.30 am – Key Biochar Research Needs. **Dr Saran Sohi**, UKBRC

12.35 – 1.00 pm – Engineering Principles in Biochar Production, **Dr Ondřej Mašek,** UKBRC

1.05 – 1.55 pm – Lunch – balcony

Afternoon Chair: Dr. Simon Shackley, UKBRC

2.00 – 3.30 pm – Break Out Groups

Facilitators: Saran Sohi, Stuart Haszeldine, David Manning, Ondřej Mašek, Jason Cook, Elisa Lopez-Capel, Simon Shackley

Scribes: to be appointed

3.35 – 4.00 pm – Coffee Break on the balcony

4.05 – 4.30 pm – Integrated Findings of the Break Out Groups

Discussion led by the Chair

4.35 – 5.00 pm – Wrap Up: How do we move forwards?

Discussion led by Stuart Haszledine

RECEPTION

5.15 to 6.45 pm: Reception Hosted by UKBRC or Researchers, Stakeholders and the Media - Atrium/Balcony

Guest Speaker: Professor Aubrey Manning OBE, FRSE, FIBiol

Brief Account of the Workshop

Prof. Stuart Haszeldine

Prof Haszeldine opened the day with an introduction. The UK Biochar Research Centre (UKBRC) is a parallel group to the Scottish Centre for Carbon Storage. Whilst the latter was set up to look at capturing carbon from power stations (CCS), the UKBRC extends the research into removal of carbon from the atmosphere. Biochar is a complex issue with many small players researching various aspects but there is a need for systematic research looking into questions such as the life-cycle of biochar carbon, soil impacts, and the value of pyrolysis-biochar in energy terms, soil improvement, climate and waste management. Of these four areas, there needs to be positive impacts in at least one or two of these areas, and ideally in all four. For a technology to be realised, it needs to move up the scale from academic research to 'readiness' (i.e. from theories to practical implementation). How can research shorten the lead-time from R&D to development and deployment. Some groups see themselves as ready for deployment, whereas others do not.

There is much contradictory evidence and regulators need robust and reliable information to develop and implement policy and rules governing the industry. The Centre has funding, mostly from the Engineering and Physical Sciences Research Council (EPSRC), of £2m over 5 years. Its mission is to weigh-up the evidence base - can Government and business make safe and secure decisions on biochar? To do this, there needs to be reliable manufacturing and categorisation and classification of different biochars, the process needs to be de-risked and monitored (e.g. in the CDM) and so on. The Centre lies between biochar's proponents (e.g. the International Biochar Initiative (IBI) and Jim Hansen) and those against it (e.g. BiofuelWatch and George Monbiot).

Dr John Gaunt

Dr Gaunt, an adjunct Associate Professor, College of Agriculture and Life Sciences, Cornell University and Carbon Consulting LLC delivered the keynote speech. He has a soil science background and believes that biochar research is driven by the need to reduce CO_2 concentrations in the atmosphere, which is predicted to rise to 650ppm and needs to be stabilised at 450ppm (requiring 35Gt CO_2 equivalent reduction per year by 2030 Vattenfall estimate).

Biochar offers an almost unique potential to drawn down CO_2 from the atmosphere, in contrast to strategies that reduce our rate of emissions. Annually, anthropogenic sources emit 7 - 9 Gt (Gigatonnes) carbon into the atmosphere, which is a small fraction of global carbon fluxes (soil, oceans etc). The flux of C through plants is 120 Gt of C annually, if we accept that when converted to biochar 20% of C captured through photosynthesis is stabilised against short term release back to the atmosphere the annual hypothetical potential for stabilisation is 24 Gt C (88 Gt CO_2e).

Understanding of biochar's behaviour in soil has been drawn from studies of ancient terra preta soils of the Amazon and other soils around the world. These provide evidence to increase confidence about its long-term carbon storage properties and of the benefits of biochar to soil fertility.

Pyrolysis of biomass for the production of biochar and bioenergy produces avoided emission from a number of sources. Where the biomass feedstock (e.g. green wastes) is diverted from management in a way that led to production of nitrous oxide or methane emissions, this represents avoided emissions. These avoided emissions are; energy produced during the pyrolysis process which replaces fossil fuel use, the C stabilised as biochar represent an avoided emission (as the C would otherwise have been released as CO_2 through burning or decomposition), and finally biochar application to agricultural soil which can reduce the need for fertilisers and reduce emissions of nitrous oxide and methane.

A paper by Gaunt & Cowie (2009)[1] contains figures for the potential GHG reductions based on green waste, cattle manure and wheat straw. Summary data indicated that a single unit which can process 2t dry matter per hour (the likely size of a small scale facility) would deliver approximately 14,000 – 58,000 t CO_{2e} avoided emissions annually. Application of this biochar to agricultural land would result in a further 700 – 1700 t CO_{2e} avoided emissions.

Therefore, from a carbon trading perspective for ease of management and to reduce risk, biochar might be better disposed of in landfill, down disused coal mines or as a construction material.

In contrast to the configuration described above sugarcane crop residues present an another example of a potential biochar feedstock. Sugarcane residues used to be burned in the field to enable manual harvesting of cane, and are now frequently left in the field are removed and turned into biochar without impairing soil fertility, together with bagasse (the residue left after cane processing). This would deliver in the order of 700,000 t CO_{2e} avoided emissions for a typical Brazilian sugarcane plantation.

If biochar is to deliver a major carbon offset option, it needs to be done at the Gt scale. There is an almost infinite number of technology configuration. In order to achieve a Gt offset quickly and effectively, whilst managing risk and uncertainty, it is desirable to identify configurations of feedstock, pyrolysis technology, bioenergy and biochar product that can deliver significant offset potential and to focus on these as scalable or repeatable opportunities .

There has been a huge surge in biochar R&D, with 160 papers published in just the last year or so. Commercial pyrolysis has existed for some time, however, and technology providers are looking at the opportunities that producing biochar may offer them. Whilst it is tempting to see a long term research opportunity, the immediacy of the climate problem means that we do not have this luxury. Linear technology development models are not appropriate. The attitude of many is that biochar is not a research challenge - we should just do it. There are some players who think they could be ready to produce biochar commercially in 6 - 12 months. This provides a unique challenge and opportunity for interdisciplinary research.

Q&A

What is the negative effect on the biosphere of removing rotting biomass carbon?

Biochar creates an environment conducive to biological activity. Even aggressively harvested cereal crops leave 45% of the organic matter in the ground (e.g. roots and exudates) so removal of surface residues is not seen as a problem. In the case of sugarcane, the bagasse was traditionally burned. Even repeated removal of waste does not reduce Soil Organic Matter (SOM) as this breaks down in a relatively short timescale in the soil anyway. Other land management techniques were suggested, which would help to reduce any potential negative effects, including low tillage, microbial inoculation, and adding trace minerals to the soil.

One of the slides showed a carbon offset benefit factor 30 times smaller than other offsets. Could biochar benefit be improved by designer biochar?

Yes, trading carbon via biochar is not a good bet unless the biochar products have increased value or use (e.g. for soil improvement). The gigatonne problem means that large amounts are needed for carbon trading.

Peter Read commented that carbon is not being removed and sterilised but is being used to improve soil condition and productivity.

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[1] Gaunt, J. and A. Cowie. 2009 Biochar, greenhouse gas accounting and emissions trading. In. Biochar for Environmental Management: science and technology. Eds. Lehmann J. and Joseph S. pp.317-336

Dr Ondrej Masek

Dr Ondrej Masek works for UKBRC as a lecturer in engineering systems, spoke on the engineering principles in biochar production. Biochar (or charcoal) has been produced for thousands of years (for cooking and smelting). It is made by pyrolysis (combustion usually without air) or gasification above 300^{o}C. The product is not pure carbon but has other impurities depending on the exact process. Pyrolysis is complex - above 300^{o}C, wood carbohydrate polymers (e.g. cellulose, hemicelluloses, lignin) cross-link and smaller molecules can interact. Temperature and pressure determine the primary, secondary and tertiary processes and end products (e.g. soot, tars, polycyclic aromatic hydrocarbons (PAHs) and char) as does the feedstock used.

Slow pyrolysis (i.e. a slow heating rate, and a lower temperature) gives a high yield of biochar (solids) while fast pyrolysis, with a higher heating rate, maximises liquid products (i.e. fuels). Biomass pyrolysis is endothermic (i.e. you need to supply energy) but between 280 and 350^{o}C it becomes exothermic (giving out more energy than went into the reaction). Slow pyrolysis and temperatures below 400^{o}C increase biochar production and the process can be altered to maximise solid or liquid products.

Various biochar production methods have been developed, including microwave heating. Some are easier to scale-up than others. Simple 'earth pit' technologies only produce about 10% biochar while novel methods can achieve up to 50%. Simpler (batch) methods are cheaper and more widely available but are less efficient with limited scope for heat recovery. The industry would tend towards continuous (rather than batch) biochar production which is more efficient, can be flexible in the feedstocks type and can integrate heat use. It is however more complex and expensive. Novel processes include flash carbonisation (under pressure) which is quick while microwave pyrolysis minimises secondary products and the char has a better structure. Gas and liquid products of pyrolysis can be used for heat and/or electricity generation in a number of ways.

Q&A
What is the difference between charcoal and biochar?
They are essentially the same but charcoal usually refers to batch systems. The term 'biochar' was coined by Peter Read some 5 years ago as a more 'friendly' term.

How do biochar systems cope with mixed feedstock, such as municipal solid waste (MSW)?
MSW is potentially problematic, in part because of the concentration of heavy metals.

Does biochar produced by different methods have different properties in soil?
The char structure will differ depending on the process used to produce it, and on the feedstock but the impacts of these types of biochar on soil are not well enough understood as yet.

Dr. Saran P Sohi

Dr. Saran P Sohi works for UKBRC and is a lecturer in Soil Science for Biochar. His talk looked at the key biochar research needs. UKBRC recently received a DEFRA contract to assess biochar. What are the motivations behind biochar - is it really 'win-win'? Motivations include climate change, bioenergy, enhanced food production and commercial gain.

Biochar has soil benefits which can potentially mitigate some of the pressure from intensive agricultural methods (e.g. reducing chemical run-off). However once it has been added to the soil, it is irremovable, and biochar is not inert and its properties vary over time (e.g. nutrient benefit will decrease with time), so it is therefore vitally important to understand these properties.

Scale is also important - what quantity of biochar do we need and what is the land availability? There is also the timescale to consider - when compared to the IPCC scenarios, actual industrial CO_2e world emissions appear to be at the top end of the modelled range. Waiting for comprehensive functional understanding can slow things down. The feedstock type can also be a limitation as you can't just switch from one to another if they are too different. If we have viable pyrolysis systems now, would their priority be to produce bioenergy or deal with waste?

Some risks and limits include the fact that biochar carbon in soil could exceed organic carbon within 15 - 150 years if its application is not regulated; biochar cannot be retrieved from the soil once applied; there needs to be a global adoption of best practice; NGOs need to be involved; and seepage (direct loss) and leakage (indirect loss) both need to be understood. A portion of biochar is highly labile and this varies depending on the process used, and other abiotic and biotic factors.

Much research has been done into terra preta soils but we have no way of knowing what ancient people applied to the soil, only what we see now. Archaeologists have found charcoal kilns dating from the 1800s in the Appalachian Mountains, and these are another potentially important research site. Likewise historical and archeological charcoals of UK and EU.

Biochar application impacts soil chemistry, including that it raises soil pH (liming effect) while its nutrient content depends on the feedstock used. Physical impacts include water retention (including solutes) and bulking of the soil, although lab experiments show that bulking is transient. The albedo of the soil will also be altered; dark soils absorb more heat and in Japan charcoal is applied to the land surface to melt snow in advance of planting. There are many inconsistencies and uncertainties in our knowledge. For example, David Wardle reported that fire-derived charcoal caused a loss of forest humus[2], but there are alternative explanations for this priming effect[3]; other evidence suggests that biochar incorporation can increase soil organic matter. Reported increases in crop yields are not likely to be a direct result of the char application but due to indirect effects and we need to understand these (e.g. changes in pH or microbial ecology, the original soil type etc). Much soil research has been lab-based and results are not understood (e.g. impacts on soil based emissions of N_2O emissions).

There was no time for Q&A

Breakout Groups:

Seven breakout groups were organised which looked at motivations, risks & barriers, and research requirements for biochar. Simon Shackley reported back the top 3 for each topic and audience members added to this. More detailed notes on some of the breakout group discussions are provided in the Annexes.

Motivations
Climate benefits/CO_2 stabilisation
Soil benefits
Economics (carbon markets, increased crop yield, decreasing waste)
Sustainable development - opportunities for poor countries to gain economically
Energy production - replacing fossil fuels

Risks & Barriers
In UK - Acceptability to market and regulators
Regulatory strangulation
Public perceptions
Unknown processes in soils, including contamination by organic compounds
Cost - need for subsidies if energy is excluded
Sustainability of feedstocks

[2] Wardle, D. A., Nilsson, M. C., & Zackrisson, O. (2008). Fire-derived charcoal causes loss of forest humus. Science, 320(5876), 629-629.

[3] Lehmann, J. and Sohi, S. (2008), Comment on “Fire-Derived Charcoal Causes Loss of Forest Humus”, Science, 321: 1295c

Overseas - Corruption
Lack of regulation
Leakage onto other types of land uses (competition or conversion of land)
Lack of knowledge and/or appropriate technology

Research needs

- One group argued that some uncertainties should not hold up biochar from being deployed
- Large scale reproducibility using sugar cane, rice paddy and landfill (these can be prioritised because they are relatively homogenous land types - if you test one, another is likely to have similar properties – and between them could constitute a major part of the one gigatonne carbon storage challenge).
- Life cycle of carbon and nitrogen
- Chemical and biological impacts on soils
- Feedstocks, processes and soils standardisation procedures (for reliable scientific results)
- Net climate forcing of carbon (including albedo)
- Dissemination of information as key points for policy makers (i.e. not just in academic papers)
- Temperate vs tropical research (most in audience who were working on biochar were looking at temperate, but the greatest potential is in tropical countries)
- Soil capacity for biochar (what's the maximum load, what's the frequency of application? etc.)
- Understanding of when use of feedstocks for energy is more valuable than use of biochar as soil improvers.

There was concern noted over the 'we know enough, we can get on with it' attitude given the problems we've had over the application of 'green compost' to land for food production in the UK, and warnings that the furore in the marketplace over sewage sludge on cereal land manures on lettuces could be repeated and should not be under-estimated. John Gaunt responded by saying that we know enough about producing biochar and its offset potential but we should use low-risk routes for disposal (e.g. landfill, old coal mines) until we understand the soil science better. David Wayne wanted to add that the cost of research to answer the many question is small, at least in relation to the sums of money liable to be invested relevant projects. There was discussion about the parallels that might be drawn between various biofuel "debacles" and the biochar proposal. There was a call for a "comprehensive full accounting" to be undertaken for PBS, that allowed included all foreseeable feedback effects such as modification of the planet's albedo. It was commented that if biochar is seen to 'work', that it might be difficult to control technological quality of PBS pyrolysis, with the risk of enhanced trace gas emission, not least from stimulating the expansion of traditional charcoal manufacture. Nonetheless, it was important that standards were laid down very soon, to guide those wishing to comply with best practice.

Workshop conclusion

The final session wrapped up by asking how we (UKBRC and those present) should move forward. Stuart Haszeldine (SH) started off with mechanisms for information exchange within the gathered community - annual meetings & an up-to-date website are easier to do than more frequent meetings and quarterly newsletters. Should UKBRC join the IBI? How to collaborate?
Q - Can UKBRC speak for all and renew its mandate at an annual meeting? SH - academics have independence and don't tend to get involved in lobbying and advocacy.
Q - Agree that independence is vital for reporting negative findings and problems as well as positive findings. Knowing the pitfalls is important especially given the timescale.
Q - There should be a body which represents more than one university - we need a multi-disciplinary forum
Q - Academic societies such as the British Society of Soil Science require topics for annual meetings - biochar should be put forward for this so as to facilitate more detailed and focused discussion as well
Q - A forum should have a central place where meeting minutes are available for those unable to attend and provide a platform focused reviews on different biochar topics should be produced to distil academic papers for a wider readership
Q - A forum should have NGO input given that public perception is a potential barrier. SH - maybe politicians too?
Q - Is there an overlap between academia and advocacy? Do we need a UK Biochar Initiative?

Q - If producing a newsletter, there needs to be news to report in it (e.g. members experimenting with their own small pyrolysis units)
Q - IBI has national chapters and a monthly newsletter. Easy to say but who funds it and who takes the lead? UKBRC could produce a newsletter without having an IBI sect in UK. All should feed news to UKBRC anyway, regardless of what structures or forums exist.
Q - In addition to NGOs and public perception, waste and incineration schemes are unpopular and often thwarted by small vocal groups opposing them due to unfounded claims. How to educate and discriminate biochar from charcoal, and at the same time disseminate objective and impartial information?
Q - Academics should urge Government to decide where biochar falls - currently dealt with by DECC and DEFRA.
Q - Research conducted in UK may not be deployed here. Could Edinburgh investigate different feedstocks with equipment installed here? Query importance of field trials (?)
Q - Would DfID fund tropical research?
Q - Access to biochar is a problem - need standard UK sources of char for testing. SH - such a proposal would need supporters - 20+ indications of academic support
Q - It might be difficult to import 'uncooked' biomass for biochar production but UK has a range of soils and feedstocks, and charcoal at least is currently imported at a rate of 65,000 t per annum
Q - Such a project would require co-funding
John Gaunt - this group should share results, which is important to show the value of research to others. There is land in the UK which needs to be restored, giving biochar an early entry potential. Also golf course and back yards may have potential. Don't assume there are no opportunities for biochar in UK or temperate countries even if on a relatively small scale in the global context
Q - A biomass pyrolysing facility is being built in Munich and should open next month; production at a scale of 10kg will be possible at University of Limerick by June this year
Q - Can we produce a delegate list with emails to enable contact? A show of hands indicated that everyone was happy for this. Delegates will be emailed and asked permission/opt-out.
Q - Presentations will be available on UKBRC website
Q - Lay foundations for PR improvements - biochar is still relatively unknown even among carbon reduction circles.

Acknowledgements

Thanks to the following for preparing these notes: Mandy Meikle, Kimberley Pratt, Elisa Lopez-Capel, Saran Sohi, Simon Shackley, Stuart Haszeldine, John Gaunt, Ondrej Masek and Sarah Carter.

Annexes: Breakout Group Discussions

Whilst seven break-out groups were held, not all the groups chose to write-up a report on the discussions held. The information below is therefore not necessarily representative of the discussions in all groups.

Group 1: Moderator - Simon Shackley (University of Edinburgh, UKBRC)

Attendees: Matthew Brander (Ecometrica), Mairi Black (Imperial College London, Porter Alliance), Kimberley Pratt (Scottish Agricultural College), Phillipa Ascough (Scottish Universities Environmental Research Centre), Roger Unwin (Consultant), Emmanuel Duga (University of Reading, Soil Science Department), Dan Gaze (Centre for Alternative Technology), John Kearney (Centre for Alternative Technology), Ulrike Schwarz (J&K Trainer Brownrigg Farm) and Ulrich Loening (Centre for Human Ecology/Lothian Trees and Timber).

Motivations for Biochar:

- Carbon fixation
- Stabilisation of contaminants
- Conflicts between research and policy → risk. Where are the riskiest unknowns? We can't afford 10 years of research.
- Soil improver for agriculture – re-carbonisation, health impacts on plants, reduced runoff, carbon store, fertility, water retention etc.
- Better waste management
- Climate change mitigation
- Carbon market
- Other green house gases emissions
- Farm scale recycling and closing the loop
- Risk of loosing Nitrogen from use of manure
- Human (and others) health

What is Biochar?

There was discussion about the term biochar and whether a definition which separated it from charcoal could be found. It was suggested that charcoal was any solid material produced from biomass which was pyrolyised and biochar was, therefore, a subset of charcoal. However, other members of the group felt that charcoal was a subset of biochar. The eventual definition may focus on the function of the product rather than the physical properties of the char. There also needs to be stronger definitions of where biochar falls under UK regulations for waste management. Since it is made from biomass some people doubted whether biochar should fall under waste management at all.

Key Variables:

- Feedstock
- Production
- Soil Types/climate

Risk Management:

- Is biochar a waste or part of an agricultural process? How does this fit with current UK regulations? When is biochar a waste? It depends on the inputs and purpose of process. Nature has no waste.
- Farm assurance schemes
- Big risk: once it is in the soil, it is impossible to get biochar back
- Mobile pyrolysis units could be used to reduce transport risks
- What will DEFRA be concerned about? N cycle, regulation and definitions. What are the priorities and key policy drivers, and how does biochar impact on these priorities?
- Hyper-regulation – over regulation can stifle a new industry

- Time and money – research questions could take years to answer but climate change demands action now
- Defining the size of the system is required – if biochar is implemented at the local level then this could reduce the risks.
- Trade-off between risks
- CDM Vs VCS
- Lack of incentives
- Public perception and the track record of biofuels

Research Questions:

- What is the difference between biochar and soil carbon/ stabilised organic matter? How do we measure biochar? Look at the baseline before biochar is added and compare to experimental data.
- How should carbon credit methodologies be implemented? Research base for the baseline data needs to be defined and quantified.
- What are the differences between tropical and temperate (UK) biochar datasets?
- Should a UK/international body be set up to respond to criticism of biochar?

Top Three:

Motivations:

1. Carbon fixation/ climate benefit
2. Soil Improvement
3. Economic benefits

Risks (UK):

1. Acceptability to the market
2. Strangulation by regulation
3. Uncertainty associated with new agricultural practices

Risks (BRICS):

1. Leakage/ Land use
2. Complexity for verification – so many unknown variables
3. Under-planning

Research Questions:

1. Carbon and Nitrogen life cycles
2. Impacts on soil: physical, chemical and biological
3. Agronomy

Group 2: Moderator - Elisa Lopez-Capel (Newcastle University and UKBRC)

<u>**Key Motivations**</u>

Categories

-Climate change: adaptation, carbon sequestration, positive benefits (increase yields), indirect benefits (stop leakage), more efficient land management (reclaimed land, set-aside, avoid de-forestation)

-Mitigation with no change in lifestyle

Full list of categories

1. Carbon credits (poverty alleviation) →1 vote
2. Carbon capture
3. Adaptation
4. Energy for poor people
5. Waste management →1 vote
6. Health benefits
7. Cleaner energy
8. Landfill diversion
9. Climate change (reduce emissions) →8 votes
10. Sustainable cycle (land use, yields, energy) →1 vote
11. Flexibility (food-energy balance)
12. Security (Energy)
13. Economics (viable)
14. Land productivity
15. Public awareness/politicians

Reporting back (shortlist and reason)

Carbon credits (poverty alleviation) →1 vote because of poverty alleviation

Sustainable cycle (land use, yields, energy) →1 vote because of food security

Climate change (reduce emissions) →8 votes because of C capture and adaptation

<u>Risks and barriers (UK)</u>

Categories

Some defined below

Full list of categories

1. Energy pays more than C credits
2. Sustainability (nutrient dynamics, labile SOM depletion if increase amount of biochar?)
3. Change is soil chemistry (needs to be fully understood, CEC, pH, mineral…)
4. Which carbon can I get carbon credits for? Validation problem. Credits for reduce use of fertilizer, soil C content, more for recalcitrant than labile C?
5. Production of GHG. Whole process level information (feedstock-transport-power plant..), trap C but what about NOX? →1 vote
6. Positive benefits not guarantee→1 vote
7. Uncertainty of impact of stability of soil carbon (C/N ratio and C pools)
8. Lack of knowledge: need more research, method and technique limitations (lab experiments may not be relevant in field situation, adequate monitoring, economics, wrong methods?) →4 vote
9. Competing industries (waste management incineration, AD/solar/wind/…)
10. Timescale: lack of datasets collected at the right scale (representative of long term) →1 vote
11. Public acceptability: No back up from regulators, politicians, general public. →2 vote

Reporting back (shortlist and reason)

Lack of knowledge (scientific etc) → therefore there is a lack of support from regulators, research councils, politicians, public

Production of GHG→ from feedstock production, thermal process, soil application

Public acceptability→ social acceptance is low

<u>Risks and barriers (BRIC/DC's)</u>

Categories

Full list of categories

1. Previous ones described for UK
2. Corrupt governments/agencies→2 vote
3. Monitoring by corrupt governments/agencies→1 vote
4. Lack of infrastructure/capital→2 vote
5. Food security/ poverty
6. The go ahead without knowledge/understanding/lack of regulation→2 vote

Reporting back (shortlist and reason)

1. Corrupt governments/agencies
2. Lack of infrastructure/capital→ not economically viable at large scale (so that it can make a noticeable impact)
3. The go ahead without knowledge/understanding/lack of regulation→ lack of planning and regulations. This could cause an economical, environmental and health risk, and have a negative impact of the success of biochar implementation.

<u>Research Barriers. How can researchers address these challenges?</u>

Barriers

1. Funding support to address the lack of knowledge
2. Limitations of methods and techniques available. Some techniques are very expensive and not suitable for large number of samples. There is a need for rapid screening techniques
3. Only short term answer achievable
4. Need to prioritise: carbon capture in developed countries versus agricultural benefit in developing countries.
5. Timescales

How can researchers address these challenges? And by when?

When → IPCC dictates the deadlines 2012? 2050?

How:

- Obtain information from existing operating pyrolysis plants
- Use information available form 4 year studies and try to extrapolate
- Carbon capture can be done. The technology is available, even if simply burying biochar.
- Waste management
- We can help with (although not fully address) the Gt scale

Group 3: Moderator – Ondrej Masek (University of Edinburgh, UKBRC)

Motivations

1. Reduce emissions
2. Financial incentives → identified as major incentive
3. Easiest option for CCS → identified as major incentive
4. Soil conditioner → identified as major incentive
5. Waste disposal
6. Distributed energy
7. Avoided land claim
8. Local ownership / flexibility

Risks

- Soil fertility effect may be absent →identified as major risk
- Stability
- Contamination
- Irreversibility
- Insufficient regulations and misdirected incentives →identified as major risk
- Threat to wildlife
- Non-sustainable feedstocks →identified as major risk
- Impact on food quality
- Nutrient loss
- Forest / soil fire
- For ground-stored biochar – lifetime?

Barriers

- Risk assessment strategies
- Public perception
- Over regulation

Research questions / objectives

- Basic characterisation and standardisation of resources and processes
- Learn from biofuels – sustainability, Life Cycle Assessment
- Develop framework for regulation development
- Dissemination of findings to policy makers

Group 4: Moderator – Stuart Haszeldine (University of Edinburgh, UKBRC)

Motivations for biochar

1. Profits from the system
2. Carbon markets
3. Sustainable development (including scalar / land area issues)
4. Fertility (also can aid germination and establishment of seeds in the soil).
5. Nutrient retention
6. Greenhouse gas reduction → identified as major incentive
7. Health benefits risk
8. Landfill offset
9. Is biochar enough? (it's a question worth answering in the changing climate)
10. Alternatives are not abundant for CO_2 draw down / CCS technology

The economics

Biochar by itself is not economic; the value is derived from an integrated approach. 50% of cellulose can produce useful and valuable chemicals. Carbon trading also is important as it may enable otherwise un-economic schemes to be feasible; however the extent is unknown, particularly in the current economic crisis.

Risks and barriers

- Demonstrable technology → Primary barrier
- Regulations → Secondary barrier
- Profit → Secondary barrier
- Public perception
- Health (risk to humans)
- Mobility (cheap batch production is available however)
- Land availability
- Feedstock competition (anaerobic digestion, mass burn in cultivation, burning)
- Business models
- Costs (including capital costs, the risk is that the technology may not operate at an economic scale).

Research challenges & How to move forward

- Prove technology – pilot demonstrations to remove / reduce the risk
- Increase understanding of revenue and ongoing income streams available
- Work with regulations / policy drivers
- Verification
- Time is imperative
- Large scale field trials in most important areas first (Brazil, Africa)
- Focus on sugarcane and rice husks
- Development and manufacture of feedstocks
- Donors need incentives to provide funding – direct: Government funding, indirect: Shell etc.
- Systematic global programme
- Involve engineers
- Identify early opportunities and classifications

Group 5: Moderator – Saran Sohi (University of Edinburgh and UKBRC)

Motivations for Biochar

These are in an approximate order of importance for the group.

- Human [Humanity's] future – as an ethical [-moral] issue
- Maintenance of total stock of carbon in soil (as distinct from increasing it)
- Energy and fuel (especially in context of energy security)
- Climate change mitigation ([by offsetting CO2 emissions elsewhere] and lower net emission of other greenhouse gases)
- Increasing crop yields [via soil fertility]
- Food supply (as distinct from crop yield on area basis)
- Nutrient management [in agriculture] and fertiliser 'replacement'
- Agricultural sustainability [maintaining yield, harmony of farming and environment]
- Flood management, [efficiency of] water use … [water management generally]
- Water pollution [control of…] – environmental angle
- Biomass burning [minimisation of…] – air pollution (human health angle)

- Waste management (whole supply chain)
- Poverty alleviation
- Profit [and various things around this]
- Reduced pressure on [rain]forest (specifically)
- Erosion control

Risks and Barriers – UK

- Biochar may [comprehensively] “not work” – RN: [self explanatory]
- Plastic waste may be used (a benefit?)
- Wind-blown biochar (health)
- Application of biochar to natural systems where not suited, and/or leading to loss of [pre-existing] soil carbon
- “Non-carbon” benefits will not be recognised
- Loss of counterbalancing “global dimming” effect from smoke will be lost
- Earth’s albedo could be modified – RN: complex and unexpected feedbacks need to be identified and evaluated
- Impact on diversity on soil (may be changed, may be decreased, balance may be changed) – RN: carefully evaluate impacts on below-ground biodiversity
- Efficacy of agrichemicals reduced
- Store up (or beneficially neutralise?) soil contaminants
- Impacts on plant pests (beneficial?)
- Regulation (..might stifle the opportunity)
- Technology innovation [not understood]
- Under-estimation of benefits [by markets or scientifically] – RN: to fully evaluate nature and reliability of all possible benefits
- Capacity [for pyrolysis–biochar systems is ultimately and fundamentally] limited

Risks and Barriers - BRICS

Key reasons for selecting BRICS over “developing countries” for debate –

- Scale of production and NPP within a single national boundary very high
- Scale of [many individual] farms – and plantations – very large
- Scale of pyrolysis plant and ease of monitoring [biochar application] large
- Extent of rice based cropping (as a key global source of methane)
- Scale of carbon emission from other sectors within same countries are escalating [so clear choices for GHG management within, rather than trans, boundary]

Risks:

- [Knock on effects on] land-use – possible accelerated loss of forest … and associated biodiversity
- Does not deliver [promised net GHG benefit]
- Weak regulatory frameworks [but noted that these combined with flexibility and entrepreneurial culture could assist in realising the opportunities…]
- Emissions quota is larger so reducing incentive to support PBS [?]

UK BIOCHAR WORKSHOP – 1ST APRIL 2009

List of delegates: Alphabetical by Surname

Dr Paul	**Alexander**	Royal Horticultural Society
Mr Richard	**Allen**	Centre for Alternative Technology (CAT)
Dr Phillipa	**Ascough**	Scottish Universities Environmental Research Centre (SUERC)
Dr Francisco	**Ascui**	University of Edinburgh, Business School
Miss Madeleine	**Bell**	Durham University
Dr Mairi	**Black**	Imperial College London, Porter Alliance
Prof Stefano	**Brandani**	University of Edinburgh
Mr Matthew	**Brander**	Ecometria, Edinburgh
Dr David	**Brignall**	Wardell Armstrong LLP
Miss Laura	**Brown**	Durham University
Mr Matthew	**Brown**	Askham Bryan College
Dr Peter	**Brownsort**	University of Edinburgh, School of GeoSciences
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Ms Yasmin	**Bushby**	University of Edinburgh
Miss Sarah	**Carter**	University of Edinburgh
Dr Joanna	**Cloy**	University of Edinburgh
Mr Gary	**Connelly**	Ethos Energy Ltd
Mr Jason	**Cook**	University of Edinburgh, UKBRC
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Dr Rachel	**Dunk**	Crichton Carbon Centre
Dr Mark	**Durenkamp**	Rothamsted Research

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Dr Chris	**Ennis**	Clean Environment Management Centre
Corinne	**Evans**	
Ms Mariska	**Evelein**	Carbon Consulting LLC
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Mr Brendan	**Hamill**	University of Edinburgh
Mr Jim	**Hammond**	University of Edinburgh
Dr Jerry	**Harrison**	VenEarth Group
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Archie	**Hunter**	
Colin	**Hunter**	
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Mr Gerry	**Jones**	Centre for Alternative Technology (CAT)
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Dr Russell	**Layberry**	Oxford University
Mr Arthur	**Llewellyn**	Carbon Gold, London
Dr Ulrich	**Loening**	Centre for Human Ecology / Lothian Trees & Timber
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Dr James	**Mair**	Heriot Watt University
Dr Phillip	**Mann**	Oxford University
Dr Pete	**Manning**	Imperial College

Prof Aubrey	**Manning**	University of Edinburgh
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Ms Deborah	**Proctor**	Joint Nature Conservation Committee (JNCC)
Dr Barry	**Rawlins**	British Geological Survey (BGS)
Prof Peter	**Read**	Massey University, New Zealand
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