Research Councils UK Energy Programme Strategy Fellowship

Summary of Workshop on

Bioenergy

Working Document

August 2013

This is a report of a workshop held to support the development of the Research Councils UK Energy Research and Training Prospectus at Rothamsted Research Centre, Harpenden on 14-15 May 2013

Energy
For a Low Carbon Future

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Research Councils Energy Programme

The Research Councils UK (RCUK) Energy Programme aims to position the UK to meet its energy and environmental targets and policy goals through world-class research and training. The Energy Programme is investing more than £625 million in research and skills to pioneer a low carbon future. This builds on an investment of £839 million over the period 2004-11.

Led by the Engineering and Physical Sciences Research Council (EPSRC), the Energy Programme brings together the work of EPSRC and that of the Biotechnology and Biological Sciences Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC).

In 2010, the EPSRC organised a Review of Energy on behalf of Research Councils UK in conjunction with the learned societies. The aim of the review, which was carried out by a panel of international experts, was to provide an independent assessment of the quality and impact of the UK programme. The Review Panel concluded that interesting, leading edge and world class research was being conducted in almost all areas while suggesting mechanisms for strengthening impact in terms of economic benefit, industry development and quality of life.

Energy Strategy Fellowship

The RCUK Energy Strategy Fellowship was established by EPSRC on behalf of Research Councils UK in April 2012 in response to the international Review Panel's recommendation that a fully integrated "roadmap" for UK research targets should be completed and maintained. The position is held by Jim Skea, Professor of Sustainable Energy in the Centre for Environmental Policy at Imperial College London. The main initial task is to synthesise an Energy Research Prospectus to explore research, skills and training needs across the energy landscape. Professor Skea leads a small team at Imperial College London tasked with developing the Prospectus.

The Prospectus will contribute to the evidence base upon which the RCUK Energy Programme can plan its forward activities alongside Government, RD&D funding bodies, the private sector and other stakeholders. The tool will highlight links along the innovation chain from basic science through to commercialisation. The tool will be flexible and adaptable and will take explicit account of uncertainties so that it can remain robust against emerging evidence about research achievements and policy priorities.

One of the main inputs to the Prospectus is a series of four high-level strategic workshops and six in-depth expert workshops taking place October 2012- July 2013. Following peer-review, the first version of the Prospectus will be published in November 2013 and will then be reviewed and updated on an annual cycle during the lifetime of the Fellowship, which ends in 2017.

This document reports views expressed at an expert workshop held in May 2013. These views do not necessarily represent a consensus of workshop participants nor will they necessarily be endorsed in the final version of the Energy Research and Training Prospectus.

Contents

1. Overview

This document summarises the outcomes of a workshop held on 14-15 May 2013 in order to identify research and training needs in the area of bioenergy. The workshop primarily covered activities relating to the production of biomass for energy and its biological conversion lying within the sphere of interest of the Biotechnology and Biological Sciences Research Council (BBSRC) and physical/chemical conversion of biomass lying within the sphere of interest of the Engineering and Physical Science Research Council (EPSRC). Some of the discussions also covered work on sustainability supported by the Natural Environment Research Council (NERC) and bioenergy economics/social acceptability supported by the Economic and Social Research Council (ESRC).

There were 24 participants in the workshop excluding the Fellowship and facilitation teams, half of whom were academic researchers and half from government, the private sector and research funding bodies. Tony Bridgwater (Aston University and SUPERGEN Bioenergy Hub), Duncan Eggar (BBSRC Bioenergy Champion) and Patricia Thornley (Tyndall Centre Manchester and SUPERGEN Bioenergy Hub) assisted in the preparation of the workshop.

The meeting was professionally facilitated by the Centre for Facilitation Services Ltd in association with the RCUK Energy Strategy Fellowship team. This record of the meeting constitutes a working document intended to capture the outcomes of the workshop. It represents an intermediate step in the production of a full Energy Strategy Fellowship report which will set out the prospectus for energy research and training needs relating to bioenergy. It has two purposes; a) to provide a resource which can be 'mined' in order to produce the prospectus document; and b) to provide an agreed account of the workshop for archival purposes.

2. Introduction to the Workshop

Jim Skea (Energy Strategy Fellow) introduced the workshop with a presentation which outlined the background and rationale for the RCUK Energy Strategy Fellowship and the activities being undertaken. He noted the role of the Prospectus in informing the future design of the RCUK's Energy Programme. The presentation covered the following points:

- The recommendations of the International Panel for the 2010 RCUK Review of Energy;
- The conclusions regarding the high quality of the science tempered by concerns about links to policy and follow-through to commercialisation;
- The vision for the Energy Research and Training Prospectus under development by the Fellowship Team;
- The programme of strategic and expert workshops and light-touch reviews being conducted; and
- The purpose of the expert workshops and the process which through the workshop outputs would be translated and synthesised for the prospectus document.

Finally, Jim presented a conceptual framework for the bioenergy research area which the organising team had found helpful in developing the workshop (Figure 1). This was not intended to constrain deliberations and it was emphasised that the outputs of the workshop belonged to the participants and would not be edited or manipulated either by the Fellow Team or the facilitators.

In questions, Jim was asked whether the education and training needs would be covered as well as research needs and pathways to commercialisation. Training needs were within scope, but it had to be noted that the Research Councils, the primary audience for the Prospectus, currently supported training only at the PhD level and through post-doctoral research.

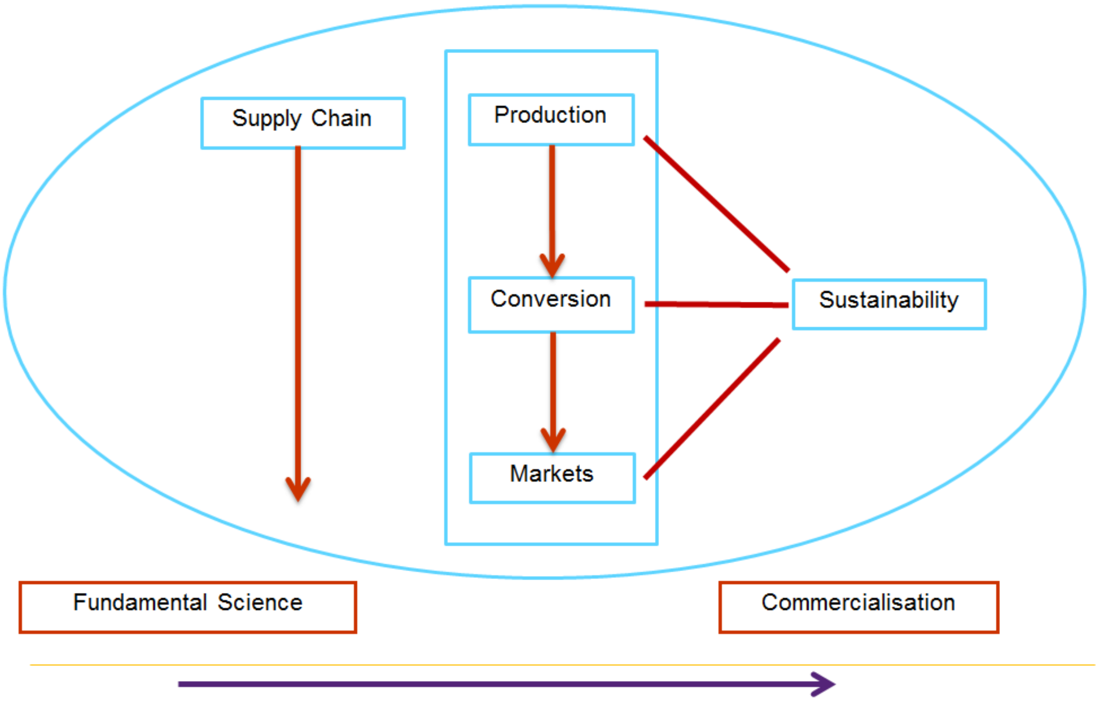

Figure 1: The Bioenergy System

3. Reflections on the current agenda

3.1 Process

Participants joined four different table groups in order to reflect on the current research agenda. Each table focused on one specific question. These were:

1. What are the main strengths of our current research in the bioenergy sector?
2. How could we improve the experience of undertaking research in this sector?
3. How could we improve funding strategies for bioenergy research?
4. If you had a magic wand what focus would you wish to see emerge for the research strategy?

Participants could change tables three times so that they had an opportunity to discuss each of the questions. However, there was no obstacle to an individual spending more than one session on one table. Notetakers were allocated to each table and briefly summarised previous discussions to newcomers. Participants were also invited to record any thoughts on the tablecloths.

At the end of the session, each table was invited to share one constructive suggestion triggered by the question "what needs our attention as a group as we shape the research strategy for the future"?

The reminder of this section summarises the table discussions and the "constructive suggestions". Details of the discussions and the tablecloth notes are recorded in Annex A. Although each question drove specific discussions, a number of themes emerged consistently across the table groups. These included: the perceived need for larger funding initiatives and longer funding cycles; the need for more joined up activity across Research Councils; the need to balance blue skies and applied research coupled with appropriate links to industry; and a perceived lack of clarity on bioenergy which affected research funding processes.

3.2 Table 1: What are the main strengths of our current research in the bioenergy sector?

The discussion of strengths provided a relatively hopeful picture of UK capabilities. Among the main themes emerging were:

- UK strengths in fundamental science, with their being more consensus about strengths in crop production but more ambiguity about strengths in conversion;
- Additional strengths in environmental sustainability and systems modelling, but weaknesses in terms of supply chain economics and public acceptability;
- UK policy is not well articulated or understood;
- Lack of joining up between Research Councils;
- Strong UK performance in converting limited research funding into outputs; and
- A perceived need for scale-up, large institutions and longer funding cycles.

More detailed points are listed in the following table, divided into broad themes: generic points; crop production; conversion; other research areas; supply chain and interdisciplinarity; and research processes.

Generic Points
• Leading edge fundamental science, application of science the main weakness • BSBEC very good at fundamental science (lignocellulose!), not good at commercialisation and scale up. • How do we take good research to wider use and application? • Good at a wide range of disciplines, but not effectively applied to bioenergy • Pockets of real excellence - "generally pretty good, but patchy" • Breadth, but is there enough depth in all areas (funding, etc)? • Excellent science in production, characterisation and conversion • Strengths are up to conversion • Overall objective of UK policy not well articulated or understood? UK needs to define its priorities.
Crop production
• Fundamental plant *and* crop science very strong (plants are not the same as crops) • Physiology, agronomy, entomology, phenotyping, phenomics, genomics, genetics, synthetic genomics • Plant cell wall biology (breaking down plant materials) • Systems biology, root growth (micorrhizal nutrients), enzyme characterisation, plant science • Soil science • Maximising yields • Weakness on harvesting – no industry to encourage it • Algae not a UK strength at the moment. But potential for macroalgae? • Microbiology application to bioenergy not yet fully materialised • Lack of thinking about crops in entire system, not just field level • Need longer-term field trials and application, plus larger-scale • Technology and equipment –lack in some areas, for example BSBEC sends samples to France. • Crop science excellent, but lacking in practical deliverability compared to other parts of Europe. • We know how to grow miscanthus, but we are not good at commercialising • Energy crops have "rescued" plant biochemistry and plant physiology, other crops have moved to genomics

Conversion
• Thermochemical conversion (strength) • Thermochemical conversion – not very strong, reflection of the funding strategy (BSBEC strategy has led to clustering of research and not joined up well) • Bacterial conversion for C1 products • Gasification • Catalysis, but not been sufficiently applied to bioenergy conversion • Shift from thermochemical to biological conversion because of perceptions of strength? • Scandinavians more successful at implementation of research in thermochemical field • Gasification - small pockets of research, but industry backing missing • Fuel research and testing not a UK strength • Research into liquid fuels currently pushed into background. • BBSRC ignores conversion • Lack big demonstration projects linking up the supply chain in the biochemical field • SUPERGEN close to commercialisation in terms of utilisation of waste fuels • Industrial partners to focus academic research on industrialisation. Attempt to deliver commercialisation. But is it a strength and has it delivered enough? • Division/lack of feedback between end user and research communities (e.g. boiler design).
Other research areas
• Environmental science • System modelling capabilities. • Integrated approaches to bioenergy – modelling, policy • UK leading edge in thinking about sustainability across disciplines (economics, social, environment) • No research base for socioeconomic considerations. • Pockets of research on economics, but not linked up • Markets not well understood and incentivised – but ESRC starting to fund research • Gaps in terms of public acceptability of bioenergy compared to nuclear and shale gas? • Lack of understanding as to why crop improvement, environmental impact assessment are important (climate change mitigation, energy security etc.)
Supply chain and interdisciplinarity
• Holistic approach has been developing and is a strength that the UK can build on • Well connected through consortia/multidisciplinarity. Not as good in terms of international comparisons • Interdisciplinarity needs improvement • Multidisciplinarity not yet good enough in the UK • Many world class activities but not joined up • Many centres of excellence, but not enough integration • EU research programmes more interdisciplinary, fewer opportunities in the UK • Opportunities to link biochemical and thermochemical conversion inadequately addressed because of Research Council responsibilities. • Lack of cross-over between different Research Council communities • Lack of links between crops (e.g. miscanthus) and downstream conversion (e.g. combustion) across all applications • Integration of bioenergy with wider energy systems is under-researched • Lack of translational research
Research Process
• UK performs well in converting limited research funding to outputs across all metrics of excellence • Industry funding and collaborative research a strength, e.g. Shell miscanthus trials Need longer term strategy and commitment • For scale-up, large institutions (e.g. national laboratories/research institutes) such as those in Germany are needed

3.3 Table 2: How could we improve the experience of undertaking research in this sector?

These discussions were characterised by a high degree of consensus. The main points were:

- The benefits of larger funding initiatives and longer funding cycles;
- The need to clarify the value of bioenergy research and engender a sense of excitement and being at the cutting edge;
- The need to balance applied and blue skies research;
- Providing interactive opportunities on terms of both interdisciplinarity and international engagement; and
- Encouraging a sense of community through industrial engagement, and knowledge exchange.

More detailed points are listed in the following table, divided into broad themes: funding and contracts; policy/societal relevance; blue skies versus applied research; expanding horizons – international and interdisciplinarity; and whole systems and sharing.

Funding and contracts
• More money! • Longer and larger funding. • Continuity of groups to retain staff between contracts is important. Need more longevity, more security – longer contracts? • Capacity and capability – need to improve staff retention through longer contracts. Currently grants top out at 5 years, and don't provide as much flexibility to reassign staff as sometimes needed. • Projects should have proper end-goals and progression. • Providing the opportunity often doesn't work alone – more active promotion needed. PhDs Not very popular with industry. DTCs. Loss of traditional apprenticeships. • Industrial CASE PhD studentships as well. More opportunities for KTPs, allowing PhD students to move to postdocs and industrial partnerships. Bureaucracy a problem currently round them. • Issue with penalising smaller groups trying to develop new approaches and areas, with DTCs meaning they can't get PhD students. • Large numbers of NGOs etc have funding for academics here – but they have to be seen to make money and achieve their goals.
Policy/societal relevance
• Needs to have a 'cutting-edge' exciting feel to the sector. • Need to see the relevance and impact of research • Need to ensure research feels valuable in a fast-moving policy environment. This field is very subjective to global and national policies – very complex environment. • People need to feel that there's a future in the area. This area mostly exists because there's seen to be a need from policy. Bioenergy research started in the 80s-90s due to energy security worries after the oil crisis. • Recruiting for bioenergy often easier than recruiting to other areas of crop science. Depends on the area, however – the quantity of bad press is putting people off some areas. • What's the right pathway for bioenergy and biofuels? What's the definition of 'best'? How do you enthuse potential researchers, given the controversy involved?
Blue skies versus applied research
• What is 'blue-sky' thinking and what is applied? Academics want to set their own problems and goals, not to be 'led' by RCUK or government. • Often difficult to get funding for blue-sky research. • Do you highlight the fundamental aspects of bioenergy, or the industrial applications? Need to do

a bit of both. • Bioenergy often not seen as 'curiosity-driven' science, but driven by needs. May not attract academics who want to ask fundamental questions. • Too applied. Sector is potentially rather disparate – impact of working isn't seen as much, as it's one part of a supply chain. • Need to be asking intellectually challenging questions in the field to attract academics. Better idea of timescales and deliverables. • Publishing in high-ranked journals difficult for bioenergy. Needs to be topical and embraced by policymakers.
Expanding horizons – international and interdisciplinarity
• Working in cross-cutting research often improves the experience – people get enthused by different and new ideas. • Working with different disciplines very enjoyable. • Opportunities to travel – secondments, sabbaticals, more opportunities in the international context. • Working with groups in Europe very enjoyable, as it exposes you to new ideas and disciplines. EU programs try to address bigger challenges, so have to be far more interdisciplinary than UK programmes. • More mobile researchers – this is increasingly happening on a EU level, and expanding to others such as China, Brazil. Marie Curie etc. Problem is people often don't go – personal reasons. • PhD students – knowledge exchange projects with other countries – provides more attractive to prospective students.
Whole systems and sharing
• Working more closely with industry – sponsoring PhD students? • Creating or encouraging more of a 'whole-system' community. • Exchanging knowledge more freely across the supply chain. • Open-source data sets. Sharing knowledge in different environments can lead to better experiences and better careers. • PhDs should be given a broad understanding of the whole supply chain?

3.4 Table 3: How could we improve funding strategies for bioenergy research?

This question provoked wide-ranging discussions which covered not only funding strategies but also industry/policy/international links and the blue skies/application balance. The key points emerging were:

- The strength of the research but weaknesses in terms of impact;
- Lack of coherence across Research Councils;
- Greater policy clarity would help define research funding strategies;
- Interactions with business;
- Balancing blue skies/applied research and who drives the decisions; and
- The strength of collaboration within the EU level but weaker links at the wider international level.

More detailed points are listed in the following table, divided into broad themes: General points; funding strategies; policy linkage; commercialisation; blue skies versus applied research; and international links. A number of research ideas also emerged.

General
• We're good at lots of things academically in the UK. We need to identify our strengths. • Strong research base but what can we deliver. Where is the impact strategy? • Fundamental science can be applied in all sorts of directions, not just bioenergy. • Bioenergy was a dirty word at recent agritech workshop.

Funding Strategies
• Individual Research Councils protect their own territory. • Clarity of role and responsibilities. Communication between key funding bodies needs improved • No easy way of funding at the boundary between research councils. Peer review process undermines interdisciplinarity. • SUPERGEN well linked with BBSRC. But it works because individuals have done it - doesn't work at high level. • Pharmaceuticals has skewed BBSRC approach. In pharmaceuticals, some people will not sit in the same room. Now waking up to differences in other sectors. • More strategic focus needed • Need to appreciate complexity and not pick winners. • Long-term commitments needed, e.g. for perennial crops. • Utility company kicking off long-term 15 year projects on bioenergy. • BBSRC reluctant to fund the same configuration beyond 5 years. Nobody likes this. SUPERGEN has a longer-term perspective. NERC also has fashion. • Consistency of support for teams as synergies build up. Could you have 10 year projects with break points? • Need bigger teams for interdisciplinarity. • Individuals not in the "inner circle" don't know where to go for funding. E.g. algae. The NIBB (*Networks in Industrial Biotechnology and Bioenergy*) discussions need engineers to cover processing but BBSRC wasn't interested. • Funding newer areas? • Criteria - synergies as well as quantitative measure of success. • EPSRC bioenergy really needs catalyst grants because of disparities within the chain. Different parts of chain funded but less available for joining up. • Bioenergy - it's a system rather than a technology or field. 1/3 plants BBSRC 2/3 conversion SUPERGEN. • The link between ETI and universities is more open now. ETI establishes contracts and is not a grant-giver, but it does do collaborative research. • Academics prefer free money. Funders want to direct. Inherent conflict.
Policy linkage
• Strategic question - what is the role of bioenergy in the system. Chicken and egg. Are we strategy or research led? • What if there isn't long-term consistency in policy? • Government need to be clear. What's the purpose - economic opportunity or climate change etc. • Criteria and targets need to be defined. To join up. What's the reasoning? Need leadership and sense of direction. • If there is no take-up there will be no research money in the long-term. Research and policy operating separately. The failure is in the policy arena. • 1m hectares would supply all off grid homes with heat. Where is GHG abatement? • No commitment to domestic Renewable Heat Incentive. • We don't communicate research insights to the policy system. Subsidies don't reflect realities. • Where do you bound bioenergy research strategy? How does it interact with other policy issues? Need to understand complexity of the bioenergy chain. Competing energy systems.
Commercialisation
• Who are the targets? Do we want companies to be the beneficiaries? In conflict with the business of incumbents? • Nothing wrong with companies benefitting from research. • Different companies want different things • Start-ups change the game. Bioenergy is a game-changer. Hard to get opinions from the large incumbents. • Improving strategies – who is it for – meet needs for E.ONs <u>*and*</u> start-ups. Are we biased? SUPERGEN has brought a mixture of industrials on. Has helped direct research. Industry has

discovered benefit – if you tweaked he focus it would be more useful.

- Need to know more about what companies do
- Need to be proactive. Business doesn't always know how to link with research.
- Researchers own data – therefore not shared between institutes. Lots of things businesses don't share.

Blue skies versus applied research

- Academics do need to think about application given current incentives.
- Engineering departments have been forced to become applied through funding conditions.
- Different research councils handle this boundary differently, e.g. SUPERGEN v BSBEC
- Crops more fundamental science at this stage. This explains BBSRC/EPSRC differences. BBSRC is further from application.
- ETI felt the need to fill in missing basic science, e.g. soil carbon project. No one Research Council had covered it.
- Who drives the process- scientific tribes or the Research Councils top down? Fundamental to application process is confusing.
- Blue skies research is interesting to read about Sunday but what about Monday morning?
- Big improvement with LCICG. But are the links at too high a level? Need detail. Breakout sessions needed to fill out.

International links

- International funding opportunities - lots at the EU level but what about beyond EU?
- Partnership awards from SIN (FCO/BIS Science and Innovation Network) get things started. But no opportunity for follow-up.
- International memoranda of understanding (e.g. with US) don't always lead to outcomes on the ground.
- UK academic researchers perform well in EU programmes. DECC developing mechanisms for collaborative industry-academia approaches to EU.
- Role of EERA (European Energy Research Alliance) mentioned. Bioenergy part of this.

Research Ideas

- Don't need to identify optimal use of biomass.
- If we want biomass boilers or GSHP need to identify what we need to do. Are there enough people trained to design and install?
- Climate-proof crops - resilience of crops - could move to two season crops. Variable climate disrupts seasonal strategies.
- Understanding how crops should be designed. Some farmers just fill in land temporarily, others long-term.
- Increasing yields on lands not suitable for food crops. Wider economic benefits of growing. Canada links to wider economic benefits for farmers.
- Need to move bioenergy beyond government subsidies - therefore research on agronomy and yields. Can we design crops that don't get soggy etc?
- BECCS - haven't even done the easy stuff (CCS and bioenergy separately).
- Need of whole systems perspective. Carbon supply chains, overall picture.
- Technological challenges/barriers (scale etc). Economic, social acceptance also matter. How does bioenergy diffuse?

3.5 Table 4: If you had a magic wand what focus would you wish to see emerge for the research strategy?

The "magic wand" question stimulated discussions ranging far beyond the boundaries of research prioritisation and funding processes. Key themes emerging were:

- The perceived policy vacuum and the negative impact of uncertainty on research as well as commercialisation;
- The need for a long-term strategy and approach;

- The importance of integrating activities across Research Councils;
- Whether academia carried any weight in decision-making processes;
- The importance of social engagement;
- A full spectrum approach for research, from production to commercialisation with blue sky research still needed for game changers. Translation is fundamental to application;
- Designing the value chain to engage all industrial players necessary in the industry;
- The role of social sciences, as well as ecosystem and sustainability aspects; and
- A decision as to whether the organising principle should be carbon or bioenergy.

The following table shows more detailed outcomes organised according to the following themes: general; policy links; societal issues; industry links; funding policy; blue skies research and application; and sustainability. In addition a number of additional research foci emerged.

General
• Definitions and concepts established at the policy level (e.g. EU) don't really work at the practical level. Better to start bottom-up, e.g. input farm level
• Do not make the assumption that most bioenergy would come from agriculture.
• Magic wand - improving crop productivity by 10% a year would be a game changer that fulfils the bioenergy strategy. Would kill land for food debate.
• Magic wand: if all crops absorbed ten times more $C0_2$
• Magic wand: find better uses for carbon. At what point does carbon become an industrial product?
Policy links
• Research is being conducted in a policy vacuum. What we do depends on a small number of government decisions.
• Research issues depend on policy changes - what if DECC cancels biomass strategy?
• Need longevity in energy supply strategy - a vision that is longer than 5 years, maybe 2-3 elections
• Other elements of society (e.g. public) sway politicians much more than academia and/or industry can, especially in the case of bioenergy. Basis of policy is more political than real, highly unscientific and emotional
• Should academia have more weight in decision-making?
• Need to have the ear of the ministers - lobbying has too much influence? Long-term vision requires academia to give politicians the courage to make long-term decisions
• Industry react to the political agenda, and therefore aren't able to act on a long-term scale
• In economic term, bioenergy doesn't necessarily need to have a climate change focus.... ...countervailing argument: biomass without a climate change focus is uneconomic as GHG targets cost £250 per person per year
• Need to recognise the co-benefits of bioenergy: employment, energy security etc.
• Problem is that 80% is an impossible target, as even wind/bioenergy is not zero-carbon, is it just a case of going for the lowest possible?
• Bioenergy is incredibly flexible on the demand side, but the problems lie more on the supply side.
Societal issues
• Currently in an environment with many uncertainties both socially and politically. Need people and politicians to understand the facts.
• Technological we are relatively ready for this, but people aren't. Need to change their perceptions.
• Magic wand: A more educated and responsible public able to address the climate change agenda.
• Not a lot of effort put into how you change people and their perceptions?
• Research strategy should inform the public of future research needs.
• Need to understand why people have these opinions in the first place, and then understand how

to influence them - role for social science?

- Need to have more expertise in social science in DECC and Defra?
- Social direction is currently away from bioenergy (e.g. Canadian wood for DRAX faces public opposition)
- Social acceptability of bioenergy? NIMBYism applies to all forms of energy

Industry links

- Research alone is not enough, need the commercialisation aspect as well
- Academia/industry/supply chain needs to fit in to a research strategy that is practically focussed, with the end goal being commercialisation
- Needs to be more focus on commercialisation, as this is critical for academic research in the long-term.
- Obvious connection between academia and industry, needs to be an understanding as to why this doesn't happen
- Can't translate academic output straight into industry -need to embed mechanisms for translation into the research
- Need to work with users in the chain - industry/research linkages. Why are the bright ideas from research so poorly taken up by industry?
- Industry is nervous to invest in something as volatile as bioenergy
- Currently supply chain has issues > hard to get it from the field to the end use (especially in the most efficient manner).
- Need to make getting bioenergy into industry more exciting. This has happened in Denmark/Austria. They have successful wood fuel heat applications, but the UK is different - often installations are undersize/over controlled/badly installed
- Translational issues in bringing in other technologies into the UK...could research issues address this?
- Academics are strongly encouraged to collaborate with industry, but the relationship is not reciprocal - what are the incentives for industry? Need to encourage them to work more with universities.
- Could incentives (similar to those for renewables, e.g. tax deductions) be provided to encourage industry to work with academia?
- Research councils don't do company start-ups
- Innovation campuses to encourage collaboration?
- What timeframe is reasonable from research to commercialisation? Miscanthus for example has stalled at the commercialisation phase even though know how to produce it and exploit it.
- Look at all the different players necessary to make a change of this scale happen, whilst also taking into account the value chain.

Funding policy

- Is the current research strategy based on a holistic view? To some extent it does, but need to understand better where the greatest opportunities lie.
- Need to integrate Research Council activities allowing councils to fund across disciplines. BBSRC tries to do this, but integration is becoming ever more important.
- Should there be just one Research Council? Is it necessary to separate the sectors? Does separation work?
- Should we have a research strategy on bioenergy? Or should we be looking to a more integrated bioeconomy, e.g. biorefineries.
- UK working by itself is not significant, needs to work internationally
- Processes & funders need to be integrated across Europe, to stop pockets of activity and excellence springing up. Currently often in separate islands. Difficult in getting the biologists and the chemists in looking at the practicalities of actually achieving these processes - currently doesn't happen
- Multidisciplinary PhDs to get rid of the tent-pole effect on research. E.a. Aberdeen University initiative identifying various multidisciplinary PhD topics
- Could a PhD cover BBSRC/EPSRC territory in 3 years?

Blue skies and application
• We need to have blue-sky research as well as an applied research focus. • Spectrum is necessary including blue-sky and applied research, as game-changers might actually be blue sky. • Blue-sky is the sexier option, but it is easier to get funding for applied. Funders like to see their ideas going somewhere • Is the blue sky/applied definition essentially arbitrary? • Need some academic leeway to work on other things about 10-20% of the time, but academia often very project focused • Is research into bioenergy already applied? • Does crop productivity need to be inherently blue sky?
Sustainability
• Upstream sustainability aspects (land use change) trips everyone up. If this issue were to be resolved, then other things would fall into place. • Should we focus on sustainability or economic viability? Are these mutually exclusive or can they go hand-in-hand? • What about ecosystem issues? • What are the economic returns that we may or may not get by focusing purely on carbon? • Need to be more subtle than focusing just on carbon with the other things coming around it (ecosystems and social systems it). Need to address methane, NO_2 etc as well (often much more potent). Carbon-nitrogen balances in crop are quite useful and are intimately linked • Are we covering bioenergy/food issues adequately? What about CO_2 effects of bioenergy strategies?
Research Focus
• Need to set some major grand challenges and address in an interdisciplinary fashion. • The grand challenges are today's political goals. But also need smaller scale challenges, e.g. efficiency, greater yields. What are the impacts of the strategy in terms of benefits to mankind? Bring the top-down approach down to understand basic practicalities. • Problem with bioenergy is that it is a system, but maybe the focus should be on carbon, rather than on bioenergy, e.g. are some applications better in materials than in energy? • Need interdisciplinary perspectives. Do we need to bring in economics and social science? • Research strategy to focus on optimum carbon use (not just sequestration). Medium to long-term understanding of where the greatest benefits of bioenergy may lie to the energy system. • More research into carbon-nitrogen and GHG cycles. • Focus on carbon - more carbon out of the air and into a crop, in a form that we can use. Sequester more in the soil, and use more in the process. Need to balance the carbon cycle. • Currently too difficult to answer ILUC issues. Need research funding in this area. • Understand what drives production at the grassroots level, and the definition of sustainability that coming out of this. • Higher yields on marginal land • How to best use miscanthus in biomass boilers. We seemed to leap into biomass research, but it is now stalling. • Bioenergy research could also look into links with electric vehicles and how these could fit together. • Waste in co-products. The biggest barriers are the focus on sustainability. Drax can't burn waste because of emissions regulations.

3.6 What needs our attention?

At the end of the session, each table was invited to share one constructive suggestion triggered by the question "what needs our attention as a group as we shape the research strategy for the future"? The following points were made:

1) Translational science is fundamental to application. We can't let go of fundamental research but

need to look at how to apply this research practically and translate it into commercialisation. Both sets of parties need to be informed of each other's activities.

2) How we can create a public wish to transition to a low carbon future

3) Need to set the UK bioenergy vision and work backwards from it.

4) Achieve integration across funding mechanisms and different bioenergy disciplines. Also, integrate both of these with industrial activities.

4. How well placed are we to tackle existing bioenergy research challenges?

Working individually, people were asked to identify how well placed the UK currently is in terms of bioenergy research capabilities so that we can meet the challenges of the future. They were invited to score these on a scale of 0-10 (0 = no chance, 10 = well set up) and explain their score on a post-it note. The following graph (Figure 2) shows the distribution of the 22 post-it comments.

The average score given by the group was 6.3 +/- 1.3. This represents a very high set of scores with most tightly clustered around 6 and one participant awarding the maximum 10 points. No-one assigned a low score to our capabilities. A very strong theme emerging from the comments is the relative strength of the UK's fundamental science in the bioenergy field, coupled with perceived weaknesses in commercialisation and application. The comments appear to converge even more tightly than the quantitative scores.

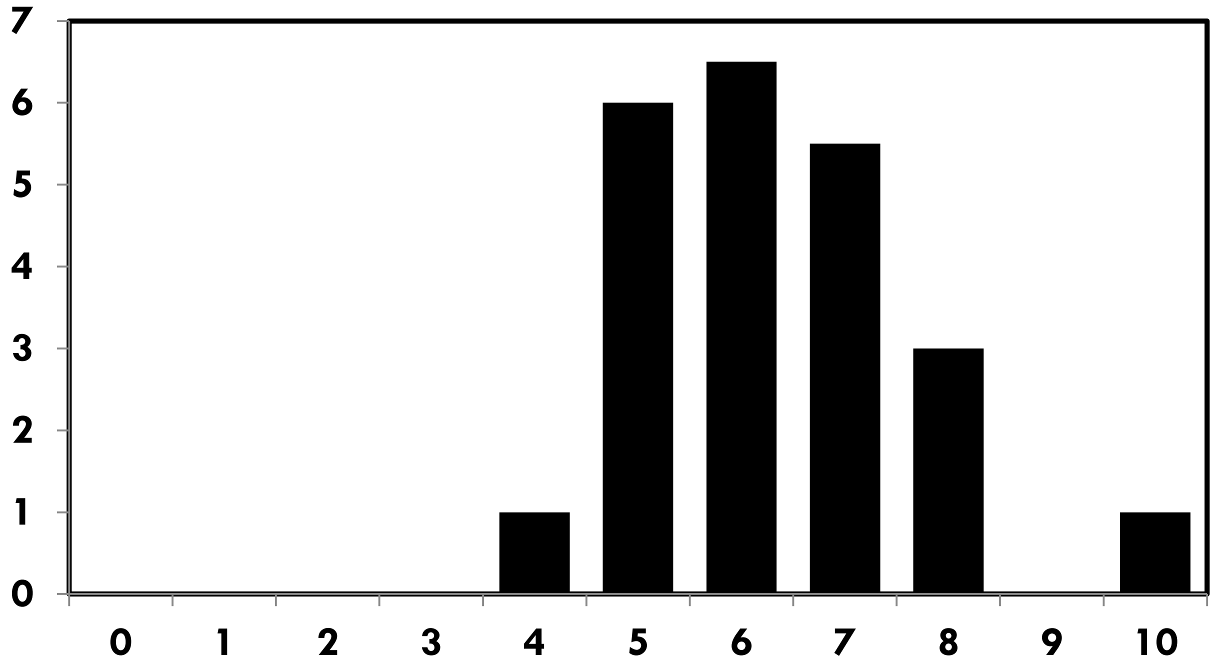

Figure 2: Distribution of perceived UK bioenergy research capabilities

Table 1 divides the results into two classes: medium capability (4-6); and high capability (7-10), set out into detailed results.

Table 1: UK's perceived capability levels to address future energy research challenges

High capability levels			
7	**8**	**9**	**10**
Good on biomass, OK on bioconversion. Average on pull-through	Good capabilities and resources compared to outside UK, but not compared to other research communities		But we won't achieve it without integration of activity
Good pockets of excellence. Reasonable coordination. Ability to bring in expertise.			
World leading bioscience, some problems around cross-discipline funding and policy/industry pull	Have the fundamental skills but further effort needed to apply them to real world challenges, i.e. take all the way through to commercialisation		
Generally a good base to start from but will need a lot of effort to see it through			
Good at TRL 1-4; erratic at TRL 5-9	Wide diversity, possibly lacking in commercialisation and detail in specific sectors		

Medium capability levels			
4	**5**	**6**	**6.5**
Breadth of research is good but patchy and not integrated in all aspects	Poor integration of science, technology, funding, and with industry	Great science, poor integrated translation.	Increasing capacity and coordination, but much more to do
	UK has come late to analysing the challenge and applying itself to the solution	Some good fundamentals but need a systems approach, policy certainty and socio-economic overview	
	Science, engineering, biology and agronomics are good. Social and economic, public awareness is low	Good research across different disciplines, increasingly integrated, but lacking depth of application in bioenergy overall.	
	Good basic – not sure if we can translate to action	Good groups collaborating well with sister groups but needs more good people working in a more integrated manner across the bioenergy sector.	
	We have high capability but it could all be easily lost	Strong research base but disconnect with political drivers and practical deliverability	
	Excellent science base but: not integrated enough; not supported at scale needed	Breadth of research is good but patchy and not integrated in all aspects	

Low capability levels			
0	**1**	**2**	**3**
No scores assigned			

5. Research 'Hotspots' and Broader Themes for Future Energy Research

5.1 Introduction to the Exercise

This exercise was designed to identify a range of topics that attendees believed should be subject to additional UK-led research in the future, and which should therefore constitute an important part of the RCUK Energy Strategy Fellowship's *Research Prospectus*.

5.2 Methodology

5.2.1 Overview

In order to identify future energy research opportunities for the UK in the field of bioenergy, the attendees were first invited to identify 'research hotspots' that could provide valuable insights, should (further) research be conducted into them. A 'research hotspot' was defined as follows:

> 'A potentially valuable area of future research, which has been identified by the Expert Workshop attendees. It is an area in which the experts believe research challenges will emerge in the future. It may be a broad and overarching question or problem'

To help guide the attendees, a couple of good-practice examples of hot spots were presented from the previous Fossil Fuel and CCS workshop.

5.2.2 How were the research hotspots generated?

The first part of the process involved the attendees working individually to generate some initial ideas about potential hotspots. The second part required the attendees to form pairs to discuss these hotspots with a partner. These were recorded on post-it-notes

Once the pairs had discussed and recorded the hotspots they were then asked to place them on several categorised poster-boards to group the results. These categories were:

- Supply Chain/Whole System
- Game-Changing
- Production
- Conversion
- Markets
- Awkward Stuff
- Sustainability
- Public Perception

Participants browsed the wall chart in order to develop a feel for the types of research hotspot that others had generated. They were then prompted by random image cards in order to identify any further research hotspots that might have been omitted. Participants were encouraged to comment on existing hotspots. This resulted in a noticeable increase in the numbers of both hotspots and comments.

5.2.3 Clustering Hot Spots at Different Scales

During the clustering exercise, participants grouped together similar hot spots in order to create research clusters representing potentially important energy infrastructure research themes. The clustering was performed by three groups corresponding to three broad, thematic categories that had emerged from the hotspots exercise. These were:

- Game changing and production

- Systems planning and operation;
- Conversion, markets and awkward stuff

Each group was assisted by a facilitator who ensured that everyone had the opportunity to provide input and that the groups had clustered and named their hotspots within the time available.

5.2.4 Grouping the Clusters Together

Participants then worked together to aggregate the research clusters into 'super-clusters'. Each group shared one of their clusters with the other groups, who were encouraged to identify any related clusters. Using a system of green, red and yellow cards, participants could confirm their support for a super-cluster, veto it or provoke further discussion. While a number of potential super-cluster arrangements were suggested by participants, more often than not these were rejected by one or more of the group because they were uncomfortable with further aggregation.

5.3 Results

In their three groups, the attendees had grouped the large number of research hotspots into 19 different clusters. These clusters were aggregated into 14 'super-clusters', using the methods described above. These 14 super-clusters are outlined in the tables below.

Cluster 1: Crop Resilience and Climate Change

Cluster Name(s)	Hotspots
1A – Resilient Crop Productivity Improvement (optimising inputs)	Crop Science – The development of increased yields of feedstocks that can adapt to markets dependent on demand. – i.e '*let the market decide*' based on criteria such as '*carbon utilisation*'
	Impacts of extreme weather events – Climate change is a long term trend, but extreme events dictate short/medium term production of food/energy and affect where people live.
	Improving crops and perennials – higher yields, lower water use, better fuel quality, using greater quantities of CO_2, better usages of N/P/K and more resilient to climate change.
	How do you develop bioenergy crops for the future climate?
	Water demand
	Speeding up multiplication and establishment of elite lines –yield, carbon, photosynthetic rates, etc.
1B – Agronomy of Bioenergy Crops on Marginal Land	Why is biomass not utilised under wind turbines?
	Increasing biomass yields on lower grade land without substantially increasing inputs (nutrients, water)
	Sustainable energy crops on marginal land – agronomy on marginal lands, high yielding plants, competitive use of land.
	Continue to identify high-yielding crops to be grown on low-grade land, including innovative, flexible production systems.
	Creation of energy crops that produce high yields on marginal land and are resilient to climate change.
	Supportive practical, specific agronomy for energy crops.

Cluster 2: Novel Solutions and Technologies

2A – Novel Solutions (opening innovation to all possibilities)	Have we captured all the energy we can from the sun?
	Are there any geo-engineering synergies with bioenergy production that can be exploited? (change in albedo etc). New area of research.
	Bioluminescent lights – lower energy consumption?
	How will we respond to new technologies and the opportunities that they represent e.g synthetic biology?
2B – Developing Novel Technologies	Continue fundamental research into lignocelluose breakdown and sugar and lignin processing
	How can we convert CO_2 into valuable chemicals?
	Artificial or man-made photosynthesis.
	Integration of bio and thermal processing – hybrid processing.
	Cost-effective ways of utilising lignin
	Application of synthetic biology to generate new 'classes' for bioconversion.

Cluster 3: Improving Product Quality + Yield during Conversion

3 – Improving Product Quality + Yield during Conversion	Catalysts for improving yield performance and selectivity of conversion and upgrading processes.
	Liquid separation technologies in conversion and processing to extract full product yield.

Cluster 4: Risks

4A - Understanding the risks of investing/switching to bioenergy crops	Security of supply
	Seasonality of supply
	Flexibility and adaptability to circumstances and environment
	Risk mitigation
4B – Residue Utilisation (continuity and security of supply)	Flexibility and security of supply
	Impact of extreme weather events -> disruptive climate change

Cluster 5: Supply Chain Logistics

5A – Economical Transport and Remote Location Use	Logistics R&D for UK applications (plant nurseries/planting/harvesting/storage/transport)
	Storage and handling of biomass fuels
	Biomass as a carbon sink with bio-products production from waste arising.
5B – Innovation in Biomass Handling Equipment	Research into agricultural machinery and operations at multi-scale UK applications.
	Improve efficiency of biomass haulage and handling.

Cluster 6: Optimisation and Integration

6: Optimisation and Integration	Utilisation of waste (assuming biomass)
	Multiple products – biorefineries
	Research into ash utilisation and how to configure/operate energy conversion technologies such that the ash may be a product, not waste.
	Process Optimisation – not just single processes but also integrated processes e.g algal biomass production, use of nutrients, carbon storage and carbon capture, energy inputs etc.
	Best use of biomass – value and flexibility. • Transport • Heat • Electricity • Co-gen
	Integration of bioenergy technologies to improve overall energy ratio/gain.
	More integration of bioenergy with bio-refineries to produce higher-value added products, substitutes for fossil-derived products – fuels, materials etc.
	Co-products from a single feedstock.

Cluster 7: Integration

7: Commercialisation	The role of standards to underpin commercialisation.
	Safety aspects of the technology
	Processes to impact small-scale local production, especially in developing countries.
	Adapting technology to the environment and local constraints
	Commercialisation and technology transfer, converting fundamental research into practical applications, taking account of the skills, understanding gaps and environment mix relevant to the UK. (e.g small interruptible supplies on a large distributed grid, better routes for domestic resources.)

Cluster 8: Connecting Different Systems to Deliver Maximum Carbon Benefits

8 – Connecting Different Systems to Deliver Maximum Carbon Benefits	Look for high-value products and maximise efficiency.
	Role and extent to which bio-based negative emissions technology (CCS) will be used in 2030-2050 and the impact on remaining energy system.
	Proving technical viability of large-scale bioenergy CCS.
	Negative carbon chains: • Soil carbon • Emissions to air • Conversion technologies – CCS • Biomass standing stock
	Flexibility and security of supply
	Impact of extreme weather events -> disruptive climate change

Cluster 9: Fuels for Transport

9A – Fuels for Transport	Fuel-flexible systems. Systems for the conversion of a variable feedstock UK mix.
	What will the future transport fuels be?
	A comprehensive bioenergy/biofuel system evaluation by performance, yield, cost, environment, socio-economics and bio-products.
	Incorporating bioenergy into public transport.
9B – Aviation Fuels	Applying liquid fuels technology to the aviation and shipping industries. Identifying the policy/regulatory mechanisms which may be able to encourage decarbonisation in these sectors.
	Production of high-performance liquid biofuels.

Cluster 10: Sustainability

10 - Sustainability	Not contaminating water by bioenergy processes.
	Satisfactorily defining sustainability.
	Food/energy/land use/water nexus
	Have we identified all the environmental costs?
	Hidden challenges in working with biomass, water availability, soil management.
	System boundaries – the bigger picture of nutrient recycling, byproduct reuse/recycle.
	Using 'Systems' theory to highlight appropriate technology and feedstock use, taking account of food/fuel/substitute materials in the light of carbon balances. Reflecting global and local appropriateness e.g can we develop feedstocks/technology here that are better used elsewhere?
	Full-system analysis in terms of ecosystem services, e.g feed-stock production, conversion technology, transport, pretreatment etc, cropping technologies.
	General integrated sustainability theme – air, water, soil, land use, biodiversity, social perceptions.

Cluster 11: Land Use

11 – Land Use	Understand better the environmental impact of land use change and create opportunity maps for different land uses in the UK.
	Impact of changing land use on biodiversity
	Understand better the natural resource base in the UK and how it can be matched to end uses.
	Most efficient use of the land resource, land use competition and land use change: • Social • Practical • Economic • Ethical
	Understanding sustainable, global land use systems in order to provide sufficient • Food • Feed • Fibre • Energy • Ecosystem Services • Biodiversity

Cluster 12: Optimum Usage of Biomass Resources

12A – Decision Support Tools	In a full system analysis how do we find the optimal solution?
	Techno-economic modelling for whole-system optimisation
12B – Optimum Use of Biomass	How do we use bioenergy sensibly? Can we consider smarter approaches e.g meeting peak demands while conserving resources?
	Given a biomass resource, what is the best way to use it in terms of resource efficiency? CHP, distributed v centralised use
	Comparative feasibility studies on different technologies
	Increasing the value of biomass by diversifying the range of production
	Identifying & understanding the most sustainability allocation of a finite biomass capacity, eg, waste streams (aviation, shipping fuels, haulage). Optimising bioenergy use.
	Multiple use feedstocks for bioenergy in relation to economic and environmental sustainability

Cluster 13: Social Acceptability

13 – Social Acceptability	How do you make bioenergy acceptable to the public? How do we improve the current public perception of bioenergy?
	Understanding the mechanisms and drivers that impact social acceptability of bioenergy.
	Understand it can/must be energy & food – not one or the other.
	Social acceptability: • Aesthetics – landscape • NIMBY – farmers et al • Multiple stakeholders • Who benefits? • Biodiversity
	Society/Public has to put its money where its mouth is: Do we want/need to reduce GHG emissions, or have cheap, secure energy, or both?
	How does bioenergy improve our welfare/quality of life?
	Public disconnect with fuel/energy production. Understanding of where energy comes from and what removing dependence on imports can deliver. Similar to understanding food production, hence moves by supermarkets to shorten supply chains.
	A change in social attitude towards energy usage is required.
	Social aspects: • Prospects for employment • Countering 'NIMBYism' • Tool for social change

Cluster 14: Novel Production Organisms

14 – Novel Production Organisms	Algae – micro + macro
	Fungi that produce biodiesel
	Algae + other new bioresources
	Time horizon for algal energy

6. Reflections on Day 1

At the beginning of Day 2, participants were asked to reflect in small groups about the work of the previous day. They were then asked to share any significant insights with the wider group. The following key points were raised:

- In the workshop there has been a lot of focus on supply chains and productivity systems. Conversion technologies seem to have been lost in the discussion. It was agreed to ensure that conversion technologies were covered in the afternoon session.
- Biomass carbon capture and storage (Bio-CCS) should be considered a game changer and should not be clustered with other topics. This subject warrants a lot of attention, as it may impact on the UK at a whole-system level. This is a longer term goal, as opposed to some of the other shorter term objectives the workshop had been discussing.
- Carbon value needs to be understood better. Biomass is the only renewable source of carbon and there could be higher value options than energy. We need to understand where carbon may go, in terms of UK and global economics. It may well be that energy is the lowest value usage in the

biomass portfolio. In the final Fellowship report, bioenergy should be put into the context into the broader bioeconomy. A lot of the technologies developed for energy can be directly applied to other biomaterials and chemicals.

- Economic valuation of the bioenergy sector and the potential markets need further consideration. There are real costs and opportunities for the UK here. Business models, job creation benefits and economic opportunities for UK need to be explored further.
- The workshop had talked a lot about crops, but also needed to focus on who is going to grow them. There is a significant concern about public perception. We rely on landowners, farmers and land workers. We need to understand what influences farmers' decisions and need to provide stakeholders with information and decision support tools to translate research into practice.
- There is a great quantity of data derived from large numbers of surveys. Do we need more, or just to utilise the existing data sets better? We need to identify data gaps and fill gaps of knowledge.
- There is a body of work focusing on bioenergy and green growth, but it tends to be very OECD-centric, and therefore perhaps not applicable to the developing world.
- Impacts of conversion need to be considered: 1) conversion of crops (characteristics), and preferred crops for fuel developers, match feedstock and processes 2) flexible fuel stocks. Need multiple feedstock tolerant processes and increase flexibility as biomass resources become scarce.
- It is important to continue crop development and other on-going fundamental research, not just explore new and interesting areas of research. The Research Councils need to fund both.
- Research on markets and business development is important –this should not be funded by the Research Councils but should be left to businesses and policy-makers. It is important to develop options and best practices instead, focusing particularly on sustainability.
- Bioenergy is a new and additional element in the conservation landscape. Bioenergy therefore needs to fit with nature conservation efforts. An evidence base of sustainable land use should be developed.
- There seems to be a couple of elements missing from the whole supply chain cluster: 1) chemistry (from crop to conversion, the actual production process) & 2) the impacts on the wider energy system and energy usage.
- The bioenergy field does not act in a purely scientific or technical way, but is greatly influenced by socio-economic and political agendas. Many of the identified research hotspots were about social aspects and perceptions, which have a significant effect on the bioenergy agenda and need to be taken into account, but are not necessarily discussions which can be usefully had by the participants of this workshop.

7. Cluster 'Deep-Dive': Communities

7.1 Overview

The purpose of this session was: a) to judge the capability and capacity of 'UK Research plc' to address the research challenges identified in the research clusters identified during the 'research hotspots" session described in section 5; and b) to suggest what needs to be done to address any shortfalls. Participants were invited to address the following questions:

1. What are the main research challenges we need to address for our research to be first class in terms of both excellence and impact?
2. To address these – what would you like to see change. For example, consider:
    a) What capabilities / capacities do we need in place?
    b) How do our ways of working need to change?

3. What needs to happen in terms of coordination and alignment to maximise success in your research area?

4. What do we need to have in place to ensure we are ready to address these research challenges (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

7.2 Method

Participants divided into four self-selected "communities of practice" to assess a first set of research clusters. "Communities of practice" were initiated by individuals who expressed an interest in a particular research theme or approach by writing the topic on a sheet of paper laid out on the floor then inviting others to join them. The aim was to have groups of no more than six people. The communities then selected priority clusters and, for each, addressed the questions listed in Section 7.1.

The following "communities of interest" were formed and addressed the research hotspots listed in Table 2:

Table 2: Communities of Interest and their Research Hotspots

Community	Cluster	Hotspot
Resilient crops	1a. Resilient crop productivity improvement (optimising inputs)	Crop Science Impacts of extreme weather events Improving crops and perennials – How do you develop bioenergy crops for the future climate? Water demand Speeding up multiplication and establishment of elite lines
	1.b. Agronomy of bioenergy crops on marginal land	Why is biomass not utilised under wind turbines? Increasing biomass yields on lower grade land without substantially increasing inputs Sustainable energy crops on marginal land. High-yielding crops to be grown on low-grade land Creation of energy crops that produce high yields on marginal land Supportive practical, specific agronomy for energy crops.
Commercialisation	7. Integration	The role of standards to underpin commercialisation. Safety aspects of the technology Processes to impact small-scale local production Adapting technology to the environment and local constraints Commercialisation and technology transfer
Carbon and economic optimisation	8. Connecting different systems to deliver maximum carbon benefits	Look for high-value products and maximise efficiency. Role and extent to which bio-based negative emissions technology will be used in 2030-2050 Proving technical viability of large-scale bioenergy CCS. Negative carbon chains: Flexibility and security of supply Impact of extreme weather events -> disruptive climate change
Land use and sustainability	10. Sustainability	Not contaminating water by bioenergy processes. Defining sustainability. Food/energy/land use/water nexus Have we identified all the environmental costs? Hidden challenges in working with biomass, water availability, soil management. System boundaries Using 'Systems' theory to highlight appropriate

		technology and feedstock use Full-system analysis in terms of ecosystem services General integrated sustainability theme
	11. Land use	Understand better the environmental impact of land use change Impact of changing land use on biodiversity Understand better the natural resource base in the UK Most efficient use of the land resource, land use competition and land use change Understanding sustainable, global land use systems in order to provide sufficient

7.3 Key points

The following key points are derived from the feedback that each community was invited to feed back to plenary at the end of the session. The specific invitation was to highlight the 'buried treasure' that they had uncovered. The detailed outcomes of the work of the four communities are summarised in sections 7.4-7.7. Annex B contains a detailed record of discussions.

7.3.1 Resilient crops

- All the work in this area could be connected in a single project or initiative
- A constant theme had been the need for long-term timescales in designing research (e.g. 10 years +)
- The need for a mix of larger and smaller field trials across the UK which are interconnected
- This could lead to the development of a database based on remote sensing and other data

7.3.2 Commercialisation

- Need a better understanding of the commercial potential of research activity
- There is no sole owner for the commercialisation of bioenergy research
- Networks are important: BBSRC clubs, SUPERGEN are gd examples, but there are some issues with participation
- PhDs: could be more interdisciplinary; industry could be involved in structuring PhDs
- Research Councils do not support MScs for bioenergy
- Scale-up is critical: the gap between pilot-scale and commercial activities needs to be bridged

7.3.3 Carbon and economic optimisation

- We should focus on the 'the carbon economy'
- We need to ensure there is a shared vision across all funders of bioenergy research
- The UK government bioenergy strategy should form the guiding vision
- We should focus on the challenge, interdisciplinary working can't be imposed
- If a top down approach is used to determine objectives, individual funding and research challenges will fall into place
- The key point is to develop the evidence base which will support decisions on the bio-economy

7.3.4 Land use and Sustainability

- The definition of sustainability had been discussed
- The need for whole systems modelling was identified
- Can existing work be augmented in order to have a whole systems perspective at different levels (e.g. farm, locality, nation, economy scale)?
- Transition implications of introducing a bioenergy policy (e.g. ecosystem services, biodiversity, food production etc.)
- How do we measure sustainability? Although expensive to set up a process, it could be used as a screening device for energy policies
- The challenge is that biomass has uses other than energy. We need to understand what is really waste (e.g. slurry?) and what are by-products that have other uses

- Is land best used for arable farming, or for bioenergy? This is where the carbon economy perspective helps.

7.4 Group 1: Resilient crops

This group focused on the UK but kept an eye on the international aspects.

7.4.1 Research challenges

Understanding carbon partitioning in plants: lignin growth; cell walls; primary metabolites v stress response; secondary metabolites v reserves

Soil/plant interactions. Plant/microbe interactions; optimising the microbial mix; carbon in the soil; carbon/water monitoring and understanding.

Efficient use of resources: light, water, nutrients

Understand growth with low inputs. Sustaining yields on marginal lands. Might need different varieties. In context of stress factors.

Yield plateaux. To include first generation feedstocks as we can't move to second generation instantly. Evidence needed at field/plot to farm level.

Abiotic and biotic stress. Tolerance to drought, flooding etc.

Matching crops to climate/land types. What are the target crops genotypes?. Climate change may make crops developed in other countries more relevant in the UK

Post production biology. Degradation, loss of yield during storage and transport.

Genome sequencing and assembly.

Research targets for first generation energy crops. Increased oil content, high starch, high protein and links to quality.

Life cycle of perennial crops. How long do they really last? How do they change over their life time.

Robust transformation technologies for all energy crops. E.g. GM

Harvesting/planting marginal land: Agricultural engineering; what type of machinery, e.g. for winter marshlands.

Smart, rapid ways of sensing: remote sensing/surveying of field properties; on-site prediction of yield; how much biomass can be delivered annually

Crop quality and checking. E.g. dipstick tests.

7.4.2 What do we need in place?

Infrastructure needed. By analogy with NERC ships/satellites. No equivalent in BBSRC domain.

Longevity. Longer term trials (ten+ years needed); longer funding periods with suitable break points.

Funding for extensive field trialling. Test plants in different environments. Comparative trials. Monitoring as well as setting up. No funding available for breeding.

Land access. Better relationships between research/industry/landowner.

Funding for phenomics platforms.

Knowledge sharing. Better relationships between research/industry/landowner. Independent extension services (e.g. ADAS) are being missed.

Sharing data and computing facilities. Genomics; crop traits and physiology; crop improvement. Data needs actively managed. BBSRC has a data sharing requirement but mechanism needs improved. Hard to raise money because high thresholds to demonstrate value. (Note:10% of some EU project funds go for data management and curation). Industrial partnerships generally figure out how data sharing works.

Training. Need PhDs embedded in large projects; could the Research Councils support Masters training if capability or requirement could be demonstrated? Recall that most Masters /PhDs go into industry or policy not academia. Need interdisciplinary PhD studentships. Few undergraduate courses in bioenergy (message for HEFCE).

7.4.3 Coordination and alignment

Cross-council funding initiatives. Thermo-chemical conversion for example falls between EPSRC/BBSRC. ERA-Net is a good example of collaboration. The approach in industrial biotechnology (IB) could be extended to bioenergy.

Communication. Make people communicate to avoid duplication.

Collective projects. Set against key challenges that require the right people to come together - but don't be too prescriptive. Consider links with industry to achieve pull-through.

Policy world. Good connections needed.

Alignment with conversion. Crop research needs to be aligned/connected with conversion research.

7.5 Group 2: Commercialisation

Given the nature of the topic "commercialisation", this group focused primarily on questions 2 and 4 – "what needs to change?" and "what do we need to have in place?". However, a small number of research challenges emerged. Participants noted that few academics had joined this group and asked whether this could indicate minimal academic interest?

7.5.1 Research challenges

- Better and cheaper enzymes that could improve the rate and selectivity of processes.
- Lignin degradation by biological pathways.
- Proactively identifying the need for and bringing independence to standards in the bioenergy field, e.g. considering chemical components within different feedstock types
- Understanding market requirements.

7.5.2 What needs to be in place?

General

- Industry needs team-workers, not individualists whereas academia focused on individual endeavour.
- Valley of death major barrier to commercialisation. How to translate academic outputs into practice?
- Black hole in the funding of demonstration plants (~$15m needed)
- Should the Research Councils act as a catalyst? However, they argue that this is not their role.
- Commercialisation doesn't fall within anybody's remit - partly TSB (but only if businesses want it)

- Need larger scale pilots and enable academics to scale up their operations. This is not currently affordable.
- There is a disconnect between demonstration plant and fully commercial scales of activity.

Academic-business links

- Do true collaborations happen through good luck or design?
- Need to be more imaginative in providing opportunities for industry to input, given time and financial constraints. Even big players don't always have the time.
- Interaction is currently ad hoc and we need more of it, underpinned by an institutional framework
- Can universities provide a mechanism to identify where academic research is going, rather than hoping industry will take it up? SuperGen has had some success in recent years, e.g. with torrefaction.
- BBSRC has run industry clubs in strategic areas but may be moving away from them.. Should there should be one in bioenergy?
- Things work occasionally, e.g. GSK gave kit to an academic research centre, (but this is rare
- KTPs are working, but IPAs aren't really working
- Collaborative research centres?

Role of the Research Councils

- Should the Research Councils fund higher level TRLs? They can support 'pilot scale' projects, but depends on definition of 'pilot scale'.
- SuperGen is a good example of things happening by accident, but small companies couldn't afford to attend SuperGen meetings. EPSRC can't actually fund industry directly, so no scope for covering SME costs

.

Trade bodies and others

- Should the Renewable Energy Association (REA) do more? Some industry and trade bodies do feed back information to Research Councils, but not often
- TSB has an ever increasing role in this area, as does ETI
- TSB's job is to take commercially ready research to industry if it is ready for it. But it can't force either end of this and generally reacts to applications from industry

Training

- Research scientists and engineers needed to be trained to understand the implications of their research and how to put the ideas into practice through all the various steps towards commercialisation
- Scientists need to understand role of economics, markets and how the business world works
- Could there be Masters degrees in bioenergy? No bespoke courses in the UK . However, courses at IBERS and Nottingham were noted.
- Industry wants conventional degrees, rather than specialist degrees.
- Can PhDs be seconded into industry? Could they receive more direction? However, the availability of CASE studentships was noted.
- EON provides 10 PhD scholarships each year
- Bioenergy research requires interdisciplinarity, but this is surprisingly difficult.

Information sharing

- Need a robust database of expertise, facilities and people with relatively open access. This should be circulated widely so people understand the state of play and available opportunities. Could TSB host this database? Could the Research Councils host this database?
- Academia and industry need an overview of successful research topics that are translatable into practice
- There is an industry network under the KTNs.
- Industry can search for bioenergy grants online, but perhaps this is not sufficiently focused?
- Could we have an academic eBay? An academic social network?

7.6 Group 3: Carbon and economic optimisation

7.6.1 Research challenges

Mapping carbon along supply chains. Methodologies for mapping that can be trusted? Common metrics. both current and future forecasting.

Understanding trade-offs. Biomass for energy/carbon as compared to other uses. E.g. different energy vectors, biotechnology/chemicals (e.g. bio-refineries), biomaterials, sequestration (e.g. CCS and biochar). What economic tipping points would make energy/carbon sequestration as opposed to biomaterials the primary focus of biomass usage? Could it be seen as a 'use hierarchy'?

Lifecycle perspective. Whole lifecycle analysis needed. Not just farming, but waste products, feedstock suppliers (forestry). Map the energy/mass balance, e.g. how much carbon does it take to make the fertilizer for the crops? Map inputs and compare with forecast use.

Counterfactuals. Counterfactuals were discussed but were seen as a sensitivitywithin models, not the focus of a full research effort. Consider known unknowns/unknown unknowns etc. How does this apply in the real world – relevance for policymakers etc.

Research impact. Who are we trying to influence? How are we trying to influence them and why? What language and knowledge assumptions are needed? Where do we want to be in 25 years time?

7.6.2 What would you like to see change? How do our ways of working need to change?

A vision. Need a carbon vision not an energy vision - the carbon economy of which bioenergy is a part. Vision breaks down to outcomes, challenges and objectives. A hierarchal structure but each stage loops back on itself.

Developing evidence base. We already have a strategy and principles. But need to understand where the opportunities lie, i.e. the additional impact of cumulative knowledge Marginal gains in one part can make a huge difference to the system. Really good research does get done – but if it doesn't' have a 'sexy' answer, it often gets ignored. Nobody wants to publish boring outputs - it still fits and provides value to understanding the system, however, and needs to be understood.

Interdisciplinarity. Scientists need to appreciate social and economic outputs and socioeconomists need to understand the limits of science. People shouldn't attempt do all things but need to understand the wider context. Needs to be encouraged rather than forced.

Training Need to train people to do the research. Capture them early, even before PhD level.

7.6.3 Coordination and alignment

A vision. The Research Councils and LCICG should develop a shared vision backed up by a confident UK direction of travel. The Government bioenergy strategy is a start.

Co-ordination. Need *genuine* coordination across the system. Different research councils have different priorities. A coherent vision across the Research Councils, bigger than the Energy Programme, is needed. Mirrored in policy, funding bodies and academia. Flexible funding – should be able to shift focus mid-project.

7.7 Group 4: Land use and sustainability

This group focused on Question 1, "What are the main research challenges we need to address for our research to be first class in terms of both excellence and impact?". It also addressed a number of cross-cutting contextual issues, reflecting the broad-ranging nature of the topic.

7.7.1 Contextual issues

Policy and general

- Need to overcome terminology barriers
- It takes time to bring energy systems online. Need to be aware of timescales when making predictions. Are there sufficiently large GHG savings in production system? And what are other environmental impacts.
- The ecosystem services approach helps frame the debate.
- Need to be clear about the drivers as policy-makers need answers now.
- How do policy decisions they affect land use nationally directly and indirectly?

Economics and valuation

- How do you make consistent value judgements?
- Need to consider economy wide impacts of land use change.
- Economics should address encompass green GDP indicators, not just conventional GDP.
- Economic valuation should be based on virtual currencies, e.g. carbon, energy balance, nutrients, not real world money

Land use

- We need to focus on the UK and UK resources. But the UK does not exist in isolation and we also need to consider how the UK interacts with global markets and the implications for sustainability and land use elsewhere.
- Not just land use issue, it's a wider resources issue concerned with trade-offs

Sustainability

- Sustainability – can we agree of what it means and is there a substitutability aspect?
- Need to define what a sustainable land use is for a particular landscape
- How do we relate sustainability and land use? A parcel of land has a resource capacity, environmental (nutrient recycling), economic (value creation), social (job creation – income for people to exist in the landscape)
- Sustainability also relates to technology and resource use (water, nutrients, etc.).

7.7.2 Research Challenges

Policy aspects

- Focus on UK and develop framework for planning and processes for sustainable supply chains.
- Understand the system so that we understand the implications of policy change. Do we have the capacity to deal with these changes?

Systems perspectives

- Defensible whole system analysis of the global bioenergy production system taking into account spatial and temporal scales.
- Full system analysis covering the entire value chain broader impacts on supporting system, including carbon stocks, nutrient balances, water balances, etc. What are the net inputs?
- Understand system fundamentals, e.g. how much available energy in 1 kg wheat straw.
- How do we make the circular economy work properly? How do we make system sustainable in terms of resources input?
- Full system analysis of waste fuelled bioenergy systems to avoid virgin inputs into system, e.g. maize silage for anaerobic digestion.

Land use change

- Understand implications of UK bioenergy, both direct and indirect land use change. What are the drivers for land use change? What are the policy implications?
- Can we adopt land use change policies without impacting biodiversity, ecology, etc? Scenarios describing how certain decisions/policies affect land use.
- Land use transition – how do ecosystems respond?
- Land management without prejudicing future operations. Consider land in terms of biggest energy potential per ha and energy balance. Gets around issue of food vs fuel.
- Why do we need to consider land use at all? Should we instead just focus on waste biomass?
- Rather than trying to get to an optimal land use model for the UK, how do we take account of all impacts of bioenergy production?

Environment and ecosystems services

- What are the environmental implications of land use planning decisions? And how would these be measured? Ecosystem services provide a coherent framework for analysis.
- Maximising resource use, utilise wastes utilisation (most waste is of biomass origin).
- What are the transitional implications, e.g. for ecosystem services.

Biomass use

- CCC biomass potential – UK land potential versus global potential for bioenergy.
- Optimum use of biomass – conversion issue?

Measurement and tools

- Measurement and quantification (economic terms, physical terms)
- Quantification of consequences of particular intervention in terms of costs and benefits (ecosystem services etc.)

- Important to have toolkits that help decision making - how do we augment existing models & frameworks
- Need robust, consistent, flexible tools to inform policy and the market.
- Need full system analysis, different from LCA methodology
- Multi-criteria optimisation models – final value of fuel, not just in terms of energy value. Do we need to consider biomass as future renewable carbon source of future?
- Screening tool for sensible bioenergy policies and incentives.
- Need economic models that account for resource - water, land, biodiversity - use
- Need to consider different scales– farm, catchment, economy – and different timescales
- Research question: quantification of the system (eg, energy balance)
- What is the potential of UK biomass energy at the moment (the baseline)?

8 Research Cluster 'Deep-Dive' 2: Community Cross-Cutting

8.1 Methodology

Participants were allocated to four groups, in which the communities identified in Section 7 were mixed. The groups were asked to cover as many of the remaining clusters/super-clusters as possible but were invited to prioritise the clusters shown in Table 3.

Table 3: Cross-community groups and their selected clusters for Deep-Dive 2

Group 1:	**4A - Understanding the risks of investing/switching to bioenergy crops**	Security of supply
		Seasonality of supply
		Flexibility and adaptability to circumstances and environment
		Risk mitigation
	4B – Residue Utilisation (continuity and security of supply)	Flexibility and security of supply
		Impact of extreme weather events -> disruptive climate change
Group 2:	**12A – Decision Support Tools**	In a full system analysis how do we find the optimal solution?
		Techno-economic modelling for whole-system optimisation
	12B – Optimum Use of Biomass	How do we use bioenergy sensibly? Can we consider smarter approaches e.g meeting peak demands while conserving resources?
		Given a biomass resource, what is the best way to use it in terms of resource efficiency? CHP, distributed v centralised use
		Comparative feasibility studies on different technologies
		Increasing the value of biomass by diversifying the range of production
		Identifying & understanding the most sustainable allocation of a finite biomass capacity, eg, waste streams (aviation, shipping fuels, haulage). Optimising bioenergy use.
	13 – Social Acceptability	How do you make bioenergy acceptable to the public? How do we improve the current public perception of bioenergy? Understanding the mechanisms and drivers that impact social acceptability of bioenergy. Understand it can/must be energy & food – not one or the other. Social acceptability: • Aesthetics – landscape • NIMBY – farmers et al

		• Multiple stakeholders • Who benefits? • Biodiversity Society/Public has to put its money where its mouth is: Do we want/need to reduce GHG emissions, or have cheap, secure energy, or both? How does bioenergy improve our welfare/quality of life? Public disconnect with fuel/energy production. Understanding of where energy comes from and what removing dependence on imports can deliver. Similar to understanding food production, hence moves by supermarkets to shorten supply chains.
Group 3:	**5A – Economical Transport and Remote Location Use**	Logistics R&D for UK applications (plant nurseries/planting/harvesting/storage/transport) Storage and handling of biomass fuels Biomass as a carbon sink with bio-products production from waste arising.
	5B – Innovation in Biomass Handling Equipment	Research into agricultural machinery and operations at multi-scale UK applications. Improve efficiency of biomass haulage and handling.
	9A – Fuels for Transport	Fuel-flexible systems. Systems for the conversion of a variable feedstock UK mix. What will the future transport fuels be? A comprehensive bioenergy/biofuel system evaluation by performance, yield, cost, environment, socio-economics and bio-products. Incorporating bioenergy into public transport.
	9B – Aviation Fuels	Applying liquid fuels technology to the aviation and shipping industries. Identifying the policy/regulatory mechanisms which may be able to encourage decarbonisation in these sectors. Production of high-performance liquid biofuels.
Group 4	**3 – Improving Product Quality + Yield during Conversion**	Catalysts for improving yield performance and selectivity of conversion and upgrading processes. Liquid separation technologies in conversion and processing to extract full product yield.
	6: Optimisation and Integration	Utilisation of waste (assuming biomass) Multiple products – biorefineries Research into ash utilisation and how to configure/operate energy conversion technologies such that the ash may be a product, not waste. Process Optimisation – not just single processes but also integrated processes e.g algal biomass production, us of nutrients, carbon storage and carbon capture, energy inputs etc. Best use of biomass – value and flexibility. • Transport • Heat • Electricity • Co-gen Integration of bioenergy technologies to improve overall energy ratio/gain. More integration of bioenergy with bio-refineries to produce higher-value added products, substitutes for fossil-derived

		products – fuels, materials etc. Co-products from a single feedstock.
	15: Conversion Technology	Sweep-up topic

8.2 Key Points

8.2.1 Research Needs

- **Public perception and social acceptability** - Biomass fears come from food riots, worries about food-producing land being used for energy or a lack of belief in climate change. What are the 'pinch points' at which the public get worried or involved, and what are the levers and mechanisms that can be employed to have a positive effect on public perception to influence social acceptability? We should learn from past mistakes, e.g. the original over-statement of GHG savings from bioenergy
- **Incentives and trade-offs** - A new type of thinking is needed on incentives. Negatives need to be communicated as trade-offs – with positive incentives, similar to the 'If you can see it, you'll benefit from it' ideas in some community wind farms. How do you balance out the different trade-offs required in a bioenergy system, how do you weight them and how do you explain that weighting to the public?
- **Objective policy assessment** - What are the mechanisms that allow you to make 'evidence-based' trade-offs, rather than trade-offs based on personal investment or vested interests? – An objective policy assessment tool could be developed, allowing an impartial, evidence-based examination similar to the NHS's NICE. Would need to be public-facing and open, and accepted by all the major public and private bodies. There would need to be an upfront acceptance that there can and will be outcomes from this tool that people will not like!
- **Fuels for transport**: How can you transport large quantities of biofuel pellets around the UK and internationally? There needs to be an understanding of port and rail constraints – wagons designed to transport coal not pellets etc – plus opportunities for inland water transport. Need to understand the logistics – little research on constructing and engineering ports and transport stations. Road transportation of solid fuels could be difficult, due to the volumes and designs of vehicle needed.
- **Spatial location and transport logistics**: Most arable land and large port facilities are in the east of the UK. Spatial mapping and optimum designs for biomass infrastructure workshops are important.
- **Storage of biofuels:** How do you control solid biomass dust? What are the key differences between it and chemical dust? We also need to understand longevity issues with regards to insects and damp. Liquid fuels such as biodiesel have a tendency to degrade – how can we prevent this? How can you handle biomass through a storage setting, and are the dust and degradation issues unique to biomass?
- **Transport fuels:** We will need liquid fuels for some time due to the internal combustion engine. How to convert biomass, especially non-food crops, to liquids? What are the best and most efficient methods of conversion – enzyme degradation, pyrolysis, gasification?
- **Aviation Fuels:** How do you actually prove the viability of fuels in aviation? The biofuel would need to be a 'drop-in' light fraction fuel similar to kerosene. There are fluid dynamics and combustion engineering issues, as well as questions surrounding ground handling and distribution. Research in this area would have to be closely coordinated with industry.
- **Rail Transport:** Is electrification the most viable option for rail, or do biofuels have a role to play?

- **Road Transport:** Fuels could be potentially ethanol/biodiesel/biobutanol/biogas. Are the barriers to uptake of biofuels in road transport policy rather than research generated? Or do the economics not work, in that oil is too cheap, limiting investment in biofuel research?
- **Thermal vs biological conversion:** Thermal conversion is very applied, biological conversion is currently too fundamental. There is more fundamental research required into better thermal catalysts. For biological conversion, more work is needed on engineering issues and crop modification.
- **Disruptive biological conversion technologies:** Synthetic biology, metabolic engineering and syngas fermentation could potentially integrate the speed of a thermal process with the focus of a biological conversion process. This may require cross-Research Council collaboration to maximise benefits.
- **Future Biofuels:** What are the desirable characteristics of future biofuels? What are the optimisation processes, both economic and technical, that need to happen to the production and conversion processes for these characteristics to be met?
- **Process/System modelling:** We need to understand the scalability of processes rather than concentrating on scaling-up. The relationships between feedstock, technology and emissions need to be understood. Each stage of a multistage process should be examined in detail, not just the quality of the final product.
- **Optimisation and Integration:** What are we optimising for? The bioeconomy can be considered as similar to the fossil economy – there is a supply of resource to multiple products, of which energy is only one. The system needs to be optimised from a whole-system perspective.
- **Biorefinery optimisation:** What are the most valuable products that can be produced from biomass, both from an economic and a carbon emissions perspective? What processes do biorefineries need to implement the production of these products, and what are the most efficient refinery routes to these products?
- **Biorefinery research challenges:** Several research challenges need to be understood with respect to biorefineries. These include cost-effectiveness, absolute versus relative greenhouse gas savings, how best to substitute for fossil fuels and the layout of modules and linkages in the refinery. Economies of scale are important – being able to scale up the processes to industrial levels is crucial.
- **Risks, flexibility and security:** Biomass has a great deal of international supply chains – how do you make these economic and secure against disruptive events? Supply chains and operations need to be flexible and adaptable against changing circumstances. Likely variations in the composition of biofuel and the tolerance of components such as biomass boilers against changing feedstock need to be understood.
- **Feedstock adaptations:** The geographic and climate impacts on feedstock in the UK need to be understood, as well as the potential international markets for UK feedstock.
- **Novel Technologies and Solutions:** Research areas include synthetic biology, hybrid bio/thermal processing, CO_2 conversion to valuable chemicals, artificial photosynthesis and novel and cost-effective uses of lignin. There is a possible synergy with forestry geo-engineering – can bioenergy production be exploited here?
- **Novel Production Organisms:** Algae, both macro and micro, could become significant players in the bioenergy sphere. Is the UK well placed to produce and utilise algae? Is algae better placed to produce high-value chemicals such as hydrogen instead of energy production? What novel conversion technologies will be needed?

8.2.2 Who is best placed to undertake this research?

- Academic Researchers
    - Biologists
    - Chemical engineers
    - Process engineers
    - Mechanical engineers
    - Crop scientists
    - Modellers
    - Social and behavioural scientists
    - Supply-chain and logistics experts
    - Biochemists
    - Geneticists
    - Climate scientists
    - Economists
- Interdisciplinary centres and cross-council programmes
- Government and policy makers
- The Research Councils – working together in a more integrated fashion
- Industry researchers and experts collaborating with academia
- Other funding bodies – ETI, TSB, even the FCO!
- International and EU collaborative projects.

8.2.3 What needs to be in place?

- **Interdisciplinary Funding:** Greater quantities of funding for interdisciplinary projects should be made available – this was seen as a priority to build and shape greater amounts of interdisciplinary working, which was commonly agreed as being nearly essential to the future of bioenergy research. It was suggested that a decent amount of research funding should be allocated to interdisciplinary research.
- **Interdisciplinary Working:** It is seen as very difficult to 'force' interdisciplinary funding, instead links should be allowed to grow organically between groups. Shared skills and learning should be encouraged. Should there be collaborative centres for bioenergy researchers in the same model as the National Centre for Research Methods, which exists for social scientists?
- **Time to grow:** Bioenergy is a relatively new discipline and is in need of long-term support in order to become established. Commitment and consistency in funding and support is important to build trust in the discipline. Longer term continuities of funding, similar to UKERC with its phase-three renewal, would be useful to support the sector.
- **Training needs:** Studentships and training programmes associated with big interdisciplinary projects, in a similar way to UKERC, would be a good way to train researchers skilled across the bioenergy sector. Training in language and communication is important to communicate and inform the wider public about research initiatives. This could be added to existing training programmes.
- **Collaborations:** Collaborative efforts between academic and industry, and between the Research Councils and TSB, are important to apply knowledge gained at basic research stages to more applied development, and to feed knowledge gained at later applied stages back into basic research.
- **Horizon scanning:** The Research Councils should ensure that they are open to proposals for the more novel technologies and solutions, and that a horizon-scanning capability is available for bioenergy to guarantee that opportunities are not lost.

- **Data platforms and knowledge sharing:** Central data platforms and mechanisms for sharing data and information between research groups and between academia and industry were seen as very important. Academics more closely associated with industry, as well as secondments and other forms of people movement, could help smooth the path between basic research and commercialisation.
- **Political and geo-political understanding:** Bioenergy has had considerable political attention in the recent past, and the large international supply chains of feedstock material lead to geo-political concerns. The drivers behind these should be understood, as they may have a bearing on future research efforts.

9 Reflective Writing

9.1 Process

The purpose of this exercise was to ensure that the finer detail generated during the workshop was not lost. It provided participants with the opportunity to build upon ideas they had formulated during the clustering and deep-dive exercises and allowed them to flag any broader issues they wanted to raise. Participants were provided with three options for the reflective review session:

Option One: ***Independent Reflection***

A room was set aside for individuals to work on their own to record their thoughts and ideas.

Option Two: ***Chat Room***

A room was provided for participants who wanted to talk through their reactions to the themes and research ideas. A note taker was present to record the discussions.

Option Three: ***Reflect and Chat***

Participants in this room first reflected individually and subsequently joined together in groups of three to discuss their individual reflections. This enabled participants to develop their ideas by 'bouncing' them off other members in their group.

Participants were encouraged to post any written output from this session into a reflections post box or email their thoughts to the organisers.

9.2 Outputs

- **A reverse auction for small pieces of academic work** to allow publicly-funded quick response work was discussed. There was a concern that the UK's competiveness was being damaged by a slow responsiveness to emerging research topics. This new 'rapid response' mechanism could also improve connections between academics and industry, by allowing joint bidding and perhaps co-funding. It was felt that TSB addresses some of this space, but by no means all. These shorter projects could be 'bolted-into' an existing Research Council-funded project, with an element of co-funding from the larger project. To assist these projects, an on-line dynamic database or directory could be set up.
- **There was a concern that training hasn't been adequately addressed** in this workshop. Bioenergy is a rapidly-changing field, are we developing the necessary academic base to succeed? What are the best ways to attract PhDs and post-docs, given the uncertainty of this field? Also need to look further out into a 5-10 year timescale – how can A-level students be attracted into this sector? Career options in the sector need to be made more obvious to young scientists and

engineers, and high-risk, high-opportunity jobs should be given higher stipends to attract the best candidates. Bioenergy training should be made more interdisciplinary, as transferable skills will help to mitigate job risks.

- **Leadership coordination** and governmental joined-up thinking are crucial for the bioenergy sector. Firm policy direction and moving towards a market which isn't ultimately distorted by subsidies is important.
- There is a need to encourage **the entry of new PIs** into the bioenergy field. The Research Councils should be less conservative and avoid favouring existing PIs. Existing PIs could be encouraged to "convert" to bioenergy research. Multidisciplinarity could be the norm for a new generation of PIs.
- **SMEs and start-up companies** could be included in funding proposals. This would be easier if long-term policy goals and aspirations provided a more stable business environment.
- **Data generated through research supported by the Research Councils** should be available to all researchers and the wider public. This would avid re-inventing the wheel and speed the road to commercialisation.
- There have been **misconceptions** at the workshop about the scope of **BBSRC's role with respect to bioenergy**. BBSRC's role is not limited to growing biomass but also covers biological conversion routes. BBSRC is also not interested solely in solid biomass. Although BBSRC does not support company start-ups, it does provide follow-on funding and enterprise fellowships.
- BBSRC is attempting to address issues such as the length of funding cycles, the balance of blue skies/applied research and industrial engagement/knowledge exchange in its Networks in Industrial Biotechnology and Bioenergy (NIBB) call.
- **Life Cycle Assessment** of greenhouse gas emissions and the wider impacts of large scale bioenergy is needed. A wide system boundary should be set to include land use change.
- **Feedstocks** need to be matched to the correct processes, taking into account the flexibility of different feedstocks. Perhaps a whole-system model is needed to take a holistic approach to the bioenergy system and its side effects – land use and ecosystems for example. This could also determine where the most optimal sources of feedstock are. There would need to be multiple potential outputs for the whole-system feedstock model to incorporate the different products the feedstocks could create.
- The **bioenergy feedstock genotypes suitable for UK conditions** will change along with a changing climate. Research Council funding calls should reflect this need. International collaboration is needed.

10 Key pointers for the Research Councils – start/stop/continue

Participants worked in groups of three to list the three issues that have emerged for each person during the workshop. They were asked how the Research Councils could assist in terms of things they could:

- Start doing/do more of
- Continue to do
- Stop doing/do less

The responses were recorded on flipcharts and each group reported back verbally on one issue they had identified. Table 4 below presents the outputs of this exercise. There was a clear preponderance of requests for the Research Councils to do undertake new or expand existing initiatives and ways of working. The request for longer finding periods, which had emerged in previous sessions, re-surfaced here. However, the most prominent request was for the Research Councils to join up better in the bioenergy field. The desire for a clear joint vision, strategic themes and cross-Council programmes were clearly signalled.

Table 4: What the Research Councils should start/continue/stop

Start doing/do more of	Continue to do	Stop doing/do less
Research Focus		
Socio-economic research	Continue research on bioenergy as a priority	Stop treating biochemical and thermochemical conversion as different
More synthesis of research, more holistic research (e.g. LACE), more of a global focus	Support crop science	
Research style		
Cross-council funding and projects		
Fund PhD students within large cross-institutional projects (value added rather than instead of post-docs)		
Longer funding periods		
Research process		
Research Councils should work on strategic themes and impact (multi-disciplinary)	Encourage networks and collaborative projects	Stop reviewing so frequently
Operate under a shared vision	Work together	Reduce bureaucracy
More cross-Council research programmes		
Interdisciplinary open calls (continuous) …with interdisciplinary review panels		
Collaborative funding; public engagement; encouraging industrial links using new mechanisms		
Take concepts further down the TRLs		
Earmark scholarships and fellowships in bioenergy		
Interact closely with funded programme during delivery phase		
Other		
Dynamic database of funded academics in energy space	Open access to data and reports	Less duplication –we already have a lot of information
	Striving for excellence being a "can do"	

11 Wrap-up and next steps

In the final session, participants were invited to make any final observations about what they were taking away from the event. The following points were made:

- It appeared to be the first time the Research Councils and different parts of the bioenergy community had been convened to work together in this way. This was very exciting.
- The process of bringing people together from different background had yielded some very good ideas. It had been a productive use of time and resources.
- The "deep dive" process had yielded some very nice treasures, e.g. the idea of long-term research trials for bioenergy that could put the UK on the map.
- The potential of independent socio-economic research had been highlighted.

On behalf of the Fellowship team, Jim Skea summarised the next steps.

- A draft summary of the workshop proceedings and outputs would be circulated to participants within three weeks.
- There would then be an opportunity for participants to comment on/add to the report. This would then be posted on the Fellowship website.
- The record of the workshop would form the primary source for the peer-reviewed bioenergy research and training prospectus to be produced over the summer. This would also be web-published.

Annex A: Reflections on the current research agenda – detailed notes

A.1 What are the main strengths of our current research in the bioenergy sector?

A.1.1 First round

- Breadth, but is there enough depth in all areas (funding, etc)
- Pockets of real excellence
- Is the multi-disciplinary aspect a strength yet?
    - Not good enough yet in UK – agreement
    - Holistic approach UK has been developing over past year is a strength that UK can build on and expand
- Are we mainly reactive? And if so, is this a strength
- BE does not lend itself to reactive research, need longer term strategy and commitment
- How do we take good research to wider use and application?
- Good start, but could be improved. Not break-through yet
- Joining up and inter-disciplinarily need to be improved
- Many different activities, world class, but not joined up
- Innovation a strength – compared to international context
- Edge: good fundamental science
    - Plant science (growing)
    - Soil science
        - Environmental science? Hesitant to broaden in context of BE, needs more effort
    - Plant cell wall biology (breaking down plant materials)
    - Entomology
    - Bacterial conversion
    - Modelling capabilities strong (Imperial – CEP, Nilay)
- "generally pretty good, but patchy"
- Good fundamental strength, but not applied strength
- Strength more bottom-up research
- Synthetic genomics (Imperial)
- Bacterial conversion (Nottingham) – C1 products
- UK traditional strength in catalysis, but has not been applied to BE conversion sufficiently
- Strengths:
    - Thermochemical conversion
    - Gasification
- Shift from TC to biological conversion – because perceived as strength?
    - Probably because of research focus of RC
    - Different angles / industries – strength?
- Expertise in crop production?
    - Maximising yields
    - Harvest side lacking – no industry to encourage it
- Not good at putting whole process together
    - F big demonstration projects on linking up entire process and supply chain (mainly biochemical)
    - G, F, NL, Scandinavians seem to achieve more than UK – more successful implementation of research (mainly thermochemical)

    - UK – gasification demonstration, small pockets of research, but industry backing missing
- Economics
    - Pockets of funding, but not linked up
- What are the main weaknesses / research gaps?
    - Recognition of weaknesses to be able to address them?
    - Good at wide range of disciplines, but not effectively applied to BE
    - Application of science main weakness

A.1.2 Second Round

- Fundamental plant and crop science very strong (not the same, not all plants are crops)
- Need to think about crops in entire system, not just field level
- Losing a lot of expertise (physiology, agronomy, phenotyping, phenomics(?))
- Energy crops have rescued plant biochemistry and plant physiology, where in other crops it's moved to genomics
- Growth in plant science application observed, after decline
- BBSRC could probably back this claim up with numbers
- BE: very well connected in consortia and in establishing multi-disciplinary teams. Maybe not as good in international comparison
- But no genuine interaction within broader research groups, eg cross-over within BBSRC and ESRC lacking, reflected in funding landscape
- Interdisciplinary research programmes funding by EU, not the same opportunities to link up funding in UK
- SUPERGEN – example of interdisciplinary cross-over in Phase I, not recently
- RC division by sector, eg biochemical vs thermochemical conversion. Processes that combine both (most do), are not adequately addressed.
- BSBEC (???) – example of interdisciplinary project
- Bioconversion – BBSRC seems to be funding more fundamental research in plant science and biology, than conversion
- In comparison to US, UK does very well in converting limited research funding to outputs (plant science, etc) across all metrics of excellence
- How do we sustain and expand this lead in a time of austerity?
- Quality of science (production, characterisation, conversion) excellent track record
- Microbiology? Application to BE not yet fully materialised
- Longterm field trials and application to BE, germ plasm and genetic resources -> good application to BE
- Technology & equipment – how does UK fare in international comparison? BSBEC sending samples to F, indicates that there may be a lack in some areas. Maybe lack of funds and expertise in operating specialised kits. Scale issues with RC? RC more focused on small to medium size, not large scale
- Integrated approach to BE – modelling, policy. UK in lead of thinking about sustainability across disciplines (economics, social, environment)
- But more needs to be done, eg, miscanthus – not considered downstream conversion (combustion) across all applications
- Division between end user communities (eg boiler design). Lack of feedback from industry to academia. SUPERGEN did try to do that, but is hasn't been replicated, in eg biochemical conversion
- Lack of translational research

A.1.3 Third Round

- Innovation process
- Genomics, genetics
- Systems biology, root growth (microrhizal nutrients), enzyme characterisation, plant science
- Thermochemical conversion – not very strong, reflection of the funding strategy (BSBEC strategy has led to clustering of research and not joined up very well)
- Should we specialise or focus on linking research up?
- BSBEC very good at fundamental science (lignocellulose!) – focussed on fundamental science. Not good at commercialisation and scale up.
- Strengths are up to conversion
- For scale-up large institutions needed, eg, G, lacking in UK. No big national laboratories or research institutes
- Weakness: lack of large institutions or industrial bodies to upscale
- Algae? Not a UK strength at the moment. Potential for macroalgae?
- Crop science excellent, but lacking in practical deliverability compared to other parts of Europe. Constraint by politics.
- Fuels and automotive industry? Fuels research and testing? Maybe some expertise in Bath, but not generally perceived as a UK strength more broadely.
- 30 centres of excellence, critical mass, but not enough integration

A.1.4 Fourth Round

- Crop science
- Environmental science
- SUPERGEN – involvement of industrial partners to focus academic research on industrialisation. Attempt to deliver commercialisation. But is it a strength and has it delivered enough?
- SUPERGEN close to commercialisation in terms of utilisation of waste fuels
- Industry funding and collaborative research, eg Shell miscanthus trials
- We know how to grow miscanthus, but we are not good at commercialising it (get farmers to grow it and someone to burn it)
- Lacking: socioeconomic considerations missing. No research base.
- Crop improvement, environmental impact assessment well understood. What is missing is understanding of why it is important (CC mitigation, energy security), and political commitment to incentives farmers and industry to invest in crop production, conversion, and application.
- Markets not well understood and incentivised
- ESRC – starting to fund research in understanding economics of BE better, across longer time scales. Integration with wider energy systems, can't be looked at isolation. Cost of carbon being considered? Also public acceptability of BE compared to nuclear and shale gas?
- BE for power and heat vs liquid fuel market? Liquid market research currently pushed into background. UK needs to define its priorities, eg. Brazil fuel security driving EtOH production.
- What is overall objective for UK? GHG savings? 80% carbon reductions by 2050? What are the social implications of this target? Not well understood.
- What is CC Act was repealed – what would happen to BE?

A.1.5 Tablecloth notes

- Crop Science
- SuperGen / focus on commercialisation
- Academic/industry link
- interdisciplinary science: a good start, but must do better

- Not linked to economic opportunity
- Present the vision of a low carbon future
- Fundamental science and technology good across many disciplines
- Limited dedicated effort to bioenergy : greatest experience in plant science
- UKERC - embedded carbon
- Waste conversion to fuels
- Combustion technology + gasification
- Independence of crop research centres
- Unique resources in genetics and genome
- Good 'consortia spirit'
- Excellent quality
- Crop research? Enzymes? Fuels? Microbes? Cell walls? Macroalgae?
- Science quality: bang for buck
- Team Working: interdisciplinary
- Modelling
- Wide range of disciplines
- Soil science
- Good links between related disciplines
- Interactions between BBSRC and EPSRC are not so good
- BBSRC more focussed on crop science and agronomy
- EPSRC more focussed on process engineering, thermochemical processes etc.

A.2 How could we improve the experience of undertaking research in this sector?

A.2.5 Tablecloth notes

- Encouraging a supply chain bioenergy community across RC's and industry
- for knowledge exchange
- technology pull
- targeted research
- Get children into science
- Do a survey of PHD students to identify why they chose a PhD in bioenergy to identify the barriers to getting folks into research
- Certainty in long-term future of industry
- being part of a bigger community
- clear commitment and future in that area
- excitement, cutting edge
- topical
- embraced by policy
- resourcing it properly and over a long time
- being part of something bigger
- cross-disciplinary approach that covers economics, social engineering, sociology, agronomy etc.
- A return to more traditional apprenticeships? More of a practical focus
- Promote the excitement of working in an interdisciplinary team
- Do we have big enough challenges? e.g. more like Carbon Trust Biofuels challenge. SUPERGEN attempts to create this

- Opportunities for collaboration working within the UK
- Earlier exposure to the industry opportunities i.e. in school syllabus
- Embraced by policymakers
- Security
- Knowledge exchange
- Image of bioenergy better than crop science but image is farming! ...perception of sustainability
- Longer term career prospects
- Energy Security drove bioenergy research with oil price in UK
- Pay higher salaries
- International components...e.g. EU projects / USA / China / India + international opportunities for exchange
- Funding and resources longer term funding on crop research is necessary
- Improve Experience RED
- Avoid subject that attracts regular press > "consumer lock-in"
- "Applied Science" > research needs to lead through to commercialisation
- Bioenergy = Lower carbon not necessary > 'renewable' only
- Fundamental vs. applied science - which is better?
- A certain comfort in having a secure funding scheme, but who calls the shots?

A.3 How could we improve funding strategies for bioenergy research?

A.3.5 Tablecloth Notes

- Force the integration through challenges
- Catalyst model is good and could be value to apply in the bioenergy sector
- Need for whole systems funding to address complex challenges
- How to manage a carbon route to best benefit?
- Bioenergy integration or show it could be integration of renewable carbon resource
- Boundary / policy footprint of bioenergy
- Leadership
- Strategic role of bioenergy
- Transparency of decision process
- Translate and communicate evidence to policy makers to ensure they act based on facts
- Sharing research outputs openly
- Ensure coverage of entire innovation chain. Make research pass along innovation chain.
- Clear idea of what the research could achieve and what objectives it would help address
- Longer-term continuity of funding, subject to review of excellence
- Build on LCICG > all detailed levels
- Barrier to farmers
- Long term: 1520 years
- regenerative
- Biomass > 1Mha could heat all off gas grid houses > 2km pipe
- Share data from all research funding
- Big companies maybe are not vehicles for change
- Small start-ups will drive game change technology
- International: Europe and beyond
- Clear leadership?

- Complexity of bioenergy: multiple technologies
- Bioenergy crops > Suitable for climate change? Too seasonal?
- 10 year research projects with midterm reviews, and monitoring of milestones
- Better communication between main players
- Linking better all env. benefits
- Linking policy with research better

A.4 If you had a magic wand what focus would you wish to see emerge for the research strategy?

- Include strategy to influence key policy decision makers, and ensure that can commercialise research outputs
- Understanding of where bioenergy could provide greatest benefits in longer term
- Facilitation of cross-disciplinary approach
- A rational spectrum of fundamental to applied science
- Different bets on bioenergy contributing "wedges" to GHG emissions reductions
- Systems perspective + industry-academic partnerships
- Crops which absorb more CO_2
- Focus on impact and work down through technology to fundamental science
- Longer term funding for projects that pass the electoral cycle: 7+ years
- Socially acceptable bioenergy food-fuel argument
- Social sciences + economics + how to live in a consumption society
- Research not in a vacuum
- Supply chain integration for UK deployment
- Integration + industry
- Research Councils, TSB, etc.
- Academics
- Pipelines
- Set ambitious targets
- What kind of targets
- Higher yields on marginal lands
- Value chains in place
- Rise linked with users in chain
- Understand why the public think what they do about bioenergy
- The public influence on politicians is high >> need to change public opinion, but how to do this?
- Industry influence is also high, and academic influence is low
- Consistency of message > evidence based
- Long-term vision: 3 to 5 years is not long enough (this applies to politicians as we'll)
- Public education on the realities of where energy comes from = social science
- how to consume less
- More applied research i.e. greater balance with fundamental science
- Carbon focused?

Annex B: Discussion in Communities of Interest - Deep Dive 1

B.1 Resilient crops

Focusing on the UK but keeping an eye on the international aspects.

Q1 research challenges

Understand carbon partitioning in plants - lignin growth, cell walls, primary metabolits v stress response (2nd metabolits) v reserves

More on yield plateaux 1gen feedstocks. Can't expect move to 2gen instantly. Field/plot evidence to farm level. > yield plateaux including 1 gen.

Efficient use of resources - light, water, nutrients.

Abiotic and biotic stress. Tolerance to drought, flooding.

Crops developed in other countries become more relevant in the UK with climate change. (But could become locally colder). Climate change needs factored in. What are the target crops genotypes. Match crops to climate/land types.

1gen = wheat, rape. Isn't that food crop area. What difference in research targets. > oil seeds increased oil content, hi starch, hi protein. Links to quality.

Longer term trials needed. 10+ Years needed

How long do perennial crops really last. How does the crop change over life time.

Robust transformation technologies for all energy crops. (eg GM)

On-site prediction of yield - how much biomass delivered in a year. Smart, rapid ways of sensing - remote sensing/surveying of field properties.

How do you harvest/plant marginal land. (What is marginal land). Engineering aspects. What type of machinery, eg winter marshlands. Agricultural engineering.

Degradation, loss of yield during storage & transport. Post production biology.

Crop quality and checking/ dipstick tests.

Genome sequencing and assembly.

(Improving fuel quality).

Soil/plant interactions. Plant/microbe interactions. Optimising the microbial mix. Carbon in soil. Carbon./water monitoring understanding. To be included in long term trials.

Understand growth on low inputs. Sustaining yields on marginal lands. Might need different varieties. In context of stress factors.

Q4/Q2 what do we need in place.

Better relationships research/industry/landowner. Land access. Knowledge sharing. Missing ADAS extension services. That are independent.

Genomics linked to good computing facilities, sharing data. Crop traits and physiology. Need a database. Crop improvement etc.

BBSRC has a data sharing requirement. But mechanism needs improved. Hard to raise money. High requirements to demonstrate value. [10% of some EU funds go for data management and curation. Data needs actively managed.

More funding for extensive field trialling. Phenomics platforms. Sounds pedestrian but privatisation - no funding for breeding. Test plants in different environments. Comparative trials. It's expensive. Not just setting up but monitoring, long term.

Long term trials.

Training (change). PhDs embedded in large products.

Masters training - RC support? Demonstrate capability or requirement?

Masters /PhDs targeted at academics. No most go into industry or policy.

Few undergrad courses in bioenergy. A message of HEFCE. Need people with skills to come through.

Interdisciplinary PhD studentships. Silo-busters!

Philosophy - longer funding periods.

Industrial partnerships figure out how data sharing works. Reasonable balance.

Q3 coordination and alignment

Thermo-chemical conversion falls between EPSRC/BBSRC.

EERA-net example of collaboration. Need more of that. A lot happens in IB but could be extended to bioenergy.

Need collective projects set against key challenges.

Need pull through link switch industry.

Cross-council funding initiatives. Need to insist on bringing the players together.

Projects that require players to come together.

Don't want to be too prescriptive. Challenge community to put in bids that bring the right people together.

Debate about whether industry should or shouldn't be required.

Need to make people aware communicate to avoid duplication.

Change

Longer term funding with suitable break points.

Analogous to NERC ships and satellites. Need infrastructure. No equivalent in BBSRC domain.

Good connections with the policy world needed.

This work must be aligned/connected with conversion.

B.2 Commercialisation

- Research challenges that industry would like to see academia tackle
- Novasines not commercially viable yet,
- Industry looking to see better and cheaper enzymes being produced. Can improve the rate and the selectivity of the process.
- Lignin degradation by biological pathways is quite specialised and not usually addressed
- Many options and variations on doing this
- BEZBEC working on this sort of thing
- Black hole in the funding requirement in order to build these plants (circe $15m needed, but faces the valley of death)
- Valley of death important in commercialisation > where does it come from and how to translate academia into practice?
- But is this the priority of the research councils?
- Should the research councils fund further down TRLs
- Scope of activities limited to universities only...not allowed to give any money to industry. Can promote 'pilot scale' projects, but depends on definition of 'pilot scale'.
- Is this actually a research council function? Or more development than research? Is is something the research councils could actually address?
- At the research level, the training of research scientists and engineers needs to happen to understand the implications of their research, and how to put these ideas into practice.
- e.g.. Specialist building in Nottingham that brought together architects and engineers (GS). Could have scientists and engineers working together in a similar manner?
- Architects and engineers is the classic example of failure
- Bioenergy in particular requires interdisciplinary. But this is surprisingly difficult.
- Need to train researchers in taking their ideas through all the various steps towards commercialisation
- Chemists need to understand role of economics.
- Even when working in the same team (TB), there are difficulties in discussing this, but hard to identify actual problem of communicating in these situations.
- Simply a difference in psyche of relative roles?
- Does this block mean that you stay forever in the ivory tower? Because you can't contribute to everything
- Maybe people need to understand better where they can contribute
-
- What about a degree in bioenergy? A masters in bioenergy?
- No current bespoke courses on this in the UK
- Is this a potential opportunity?
- Industry wants conventional degrees, rather than specialist degrees...would prefer to take on a chemist/biochemical specialist etc.
- Industry has a general problem with graduates?
- People need to identify their own limits?
- Academia focussed on individual rather than teamworking? Where industry needs teamworkers, not individualists
- Consequence of education system in the UK from H5 upwards

- Biochemical masters worked well together. Where both parties (Biologists and chemists) both contributed relevant skills to solving the problem.
- Can the university provide a mechanism to see where academic research is going, rather than researching (e.g. in torrefaction) and hoping industry will take it up, as they don't have their own resources to take it forward.
- What resources would you actually require?
- A team of people to feed your body of work into
- Do we need the university's equivalent of a careers advisory service?
- How do you actually find out about interesting research?
- Business partnerships > Cites success of SuperGen in recent years (GS), e.g. by finding out about torrefaction, and identifying other opportunities in research that may have the potential for commercialisation
- Not research that is needed, but more interaction (currently ad hoc), more of an institutional framework
- BBSRC has had it's industry clubs for years on strategic areas. Could argue they should have one in bioenergy, but perhaps moving away from industry clubs now?
- Need a robust database of expertise, facilities and people with relatively open access. Circulated widely so people understand the state of play and opportunities in an area.
- Academia and industry need an overview of successful research topics that are translatable into practice
- Should REA do more? No specific bioenergy industry association
- Some industry and trade bodies do feed back information to research councils, but doesn't happen too often
- Should this be led from the top? Should the research councils act as a catalyst for this? But RCs actively discourage this, and claim it is not their role.
- Then the problem is whose role is it actually? UKERC? UKERC did actually produce a database 5 years ago, but was limited to major consortia. Focused on a particular type of project.
- TSB has an ever increasing role in this area, as does ETI
- TSB's job is to take commercially ready research to industry if it is ready for it. PIcks relevant races for industry to run in and offers funding for them. But can't force either end of this.
- In some way reacts the the applications from industry
- Is there a place for TSB to host this database?
- Would they support the creation of such a database? A research database should be the RC's job
- There is an industry network under the KTNs
- The issue is, who's responsibility is it.
- Industry is able to search for bioenergy grants, but perhaps internet is not the most relevant vehicle for this? Too diffuse?
-
- SuperGen is a good example of things happening by accident
- In SuperGen this industrial collaboration should happen
- Small companies couldn't afford to attend SuperGen meetings, so included only the large companies
- Couldn't afford to spend 2 days away
- EON etc. was the other end of the scale, and only there out of pure interest
- But EPSRC can't actually fund industry directly, so no scope for covering costs for SME's in this sector to attend meetings
- the concept of grouping is there, but growing more organically now

- Modest consortia and adding to it
-
- Key message is that there is a need for training in this area, primarily to achieve better understanding of value chain towards commercialisation.
- Adequately covered in order to move to another cluster?
- Primarily no academics wanted to be involved in this group > sign of minimal academic interest?
- Question as to what kind of training would actually be necessary?
- When first went into academia (TB), there were much more funds available, but now can only focus on microapplications of technology.
- Which isn't enough to prove to industry that these applications are commercially viable, therefore what is the point?
- Talk of a bit of kit being scrapped > but how to transfer assets within academia? How do you actually bridge this gap?
- Academic eBay? Academic social network?
- Does happen occasionally > e.g GSK giving kit to an academic research centre (but this is a rare example)
- KTPs are working, but IPAs aren't really working
- PhDs on secondment > is this the ideal solution?
- Persuades certain people, but not entire organisations
- But PhDs working on things 10 years ahead of time? Perhaps not too relevant to work in the current area.
- Need to train people to understand better commercial viability
- Some linkages to socioeconomic aspects too
- Problem is that you can provide a different set of courses, but it's up to the students whether they actually learn anything
- You simply can't teach people who don't want to be taught
- But not to say that a training programme can't be drawn up
- What about a commercial foundation course prePhD?
- This does already happen to some extent
- Is there any investigation that goes along in parallel in research into the actual market needs?
- Some issues in applying known technologies in different markets
- e.g. heating technology that needs to be under a load into an environment with no guaranteed load, so the equipment ends up being written off as a failure, due to inadequate quality control
- Same with quality control of feedstock issues
- Failure often due to fairly basic issues
- Valuable to understanding what the marketplace actually really needs
- A lot of developments undertaken with a view to exporting
- This is the job of businesses, but should also be incorporated into some form of PhD training
- UKERC could do this at a higher level?
- Economics also come into play, as can't afford to buy the correct spec of feedstock or tech.
- Need more flexible resilient conversion technologies? Or feedstock?
- Most people design or build a conversion technology to match a feedstock
- In order to commercialise activity, need to understand what the market needs
- Biomass fuel system means different biomass being produced at different times of the year
- Matching of the fuel supply with the conversion technology is terribly important, but often ignored
- The relevant interfacing doesn't happen

- Does academia dislike being told what to research?
- TSB also can't direct industry, needs to see what they want to do before backing them
- What can ENSUS do to keep academia happy?
- Industry can't wait long enough for PhD's to finish their studies, want to act in shortterm future, not 35 years later
- But also academia doesn't understand this point of view
- Which models are effective in creating these partnerships?
- Look to Europe for examples?
- Minnow project? 5 yr project looking at soil carbon, industry funded
- Take the best parts of the SuperGen project
- What about the role of standards?
- Matching feedstocks to technology etc.
- Standards are pointless?
- Most fundamental parts of them (e.g. ash melting temperature) not included (e.g. pellet standards)
- BSI are working on this, but standards are driven by communities of interest, without a transparent process. Wasn't a fair membership to get the right parties involved.
- SEN is run by the people with the deepest pockets
- Are there standards missing for other areas of biomass? e.g. wastederived fuels
- Industry group initiative has rewritten their own standards, as SEN doesn't actually cover what they need.
- Has obvious impact on commercialisation
- There is a certain assumption that standards are always well designed >>> currently standards are inappropriate
- Research could be more proactive in identify needs for new standards, and bringing independence to standards
- Definitely a research gap here.
- e.g. considering chemical components within different feedstock types, which have the biggest effect on technologies come conversion
- TB had no idea standards were as bad that
- Need some academic input into standards development
- What about understanding the market requirements?

Key Points:

- PhD Training
- More interdisciplinary
- PrePhD commercialisation training
- Secondment opportunities
- Need to understand markets and understanding how the business world works
- Matching research efforts with relevant markets
- PhD's need more direction?
- Industry academic linkages, e.g. collaborative research centres?
- Data collection > register of research areas and contacts
- Research infrastructure
- Need larger scale pilots, enable academics to scale up their operations > academic affordable
- Demo plant > industry relevant scale

- Disconnect between them
- Funding philosophy
- Challenge for SMEs to participate
- Universities aren't allowed to provide funding for the private sector?
- Commercialisation doesn't fall within anybody's remit particular
- Partly TSB (but only if businesses want it), not the RC.
- What else?
- Lessons from SuperGen?
- 10 companies involved in first SuperGen, but never got SMEs involved. EON was most supportive, but EON, with a biomass fuelled power station, took more than 2 years to actually visit it
- EON also provides 10 PhD scholarships each year, but failed to mention this within the SuperGen project.
- Inverse relationship between the regularity of attendance and degree of clout?
- Big players sometimes don't have the time e.g. BP Biofuels
- Need to be more imaginative in making ways through which industry can input, in ways they have time to, and can afford?
- Do true collaborations happen purely through fortune? Or choosing to network?
- Should this be able to happen in a more organised fashion? Can be structurally more efficient.

B.3 Carbon and economic optimisation

Question 1: Main research challenges

Mapping carbon along chains. (supply?) both current and future forecasting. Understanding the tradeoffs – bioenergies use as carbon compared to other uses. E.g different energy vectors, biotechnology/chemicals, sequestration. (CCS and biochar). Using as chemicals – biorefineries.

What economic tipping points will make energy/carbon sequestration be the primary focus of biomass usage rather than biomaterials? Can be seen as a 'use hierarchy', rather than a simple focus. Not just farmers, but waste products, feedstock suppliers (forestry). Inputs as well – whole lifetime analysis. Needs to be mapped now, and compared with forecasted usages. Mapping the Energy/mass balance – e.g how much carbon does it take to make the fertilizer for the crops?

Which methodology do you trust for doing this mapping? Need to use common metrics that can be compared across the chain.

Research challenges: what are the counterfactuals? Provide for the 'Rumsfeld factor' – known knowns etc. The 'say what' question – how does this work apply in the real world – relevance for policymakers etc. Counterfactuals are a sensitivity within the model, not a full research effort.

Who are we trying to influence? What language and knowledge assumptions are needed? How are we trying to influence them and why? Where do we want to be in 25 years time?

Question 2: What would you like to see change? How do our ways of working need to change?

Can the Research Councils have a vision? A more coordinated vision in this area is needed. Different research councils have different priorities – need a bringing together across councils to have a coherent vision – bigger than the Energy Programme. Government Bioenergy strategy is a start. Need to move towards an evidence base to support the vision – already have strategy and principles. Tiny marginal gains in one part can make a huge difference to the system. Need to understand where the opportunities lie – additive effect of culminative knowledge. Need *genuine* coordination across the system. Flexible funding – should be able to shift focus mid-project. Mirroring in policy, funders and academia. ERP – public-private. LCICG – public sector coordination. Really good research does get done – but if it doesn't' have a 'sexy' answer, it often gets ignored. Nobody wants to publish boring outputs - it still fits and provides value to understanding the system, however, and needs to be understood.

Question 3: Coordination and alignment.

Genuine coordination at all levels. Covered a lot in the section above.

Question 4: What needs to be in place?

Two points – one is about training – scientists need to appreciate the social and economic outputs, and socioeconomists need to understand the limits of science. People shouldn't do all things – but need to understand the wider context. People aren't working in isolation. Interdisiciplinarity is very important but can't be forced – needs to be encouraged instead. Vision breaks down to outcomes, challenges and objectives. Each stage loops back – it's a hierarchal structure, but feeds back on itself at each stage. How do you generate the people to do the research? Need to capture early, een before PhD level. Not an energy vision but a carbon vision. The carbon economy – of which bioenergy is a part.

Diagram here to explain the structure – on separate sheet of paper. Immediate objective should be to get all the RCs and LCICG together and get a shared vision. Needs to be backed up by a confident UK direction.

B.4 Land use and sustainability

- Focus on UK & UK resources
- But UK does not exist in isolation, need to consider how UK interacts with global markets and implications on sustainability and land use elsewhere.
- Do land use and sust. overlap? What are the boundaries? Where do we overlap?
- But need to have UK as a starting point as a unique POV and then expand. Will get complicated very complicated, especially when considering ILUC
- Focus on UK & develop framework for planning & processes for sustainable supply chains. What are the market impacts?
- Rather than trying to get to an optimal land use model for the UK, how do we take account of all impacts of bioenergy production.
- Develop research agenda to understand implications of UK BE, both direct and indirect land use change. What are the drivers for land use change? What are the policy implications?
- Can we adopt land use change policies without impacting biodiversity, ecology, etc? What do certain decisions / policy targets have on land use, etc. Scenario development.
- Land use transition – how do ecosystems respond to this? Impacts? A lot of research in this area.
- What are the environmental implications of land use planning decisions? And how would these be measured?
- Research challenge: understand the system to a degree that if we introduce change to understand what happens? And then, do we have the capacity to deal with these changes
- What ecosystem changes occur for any land use change decision? Ecosystem services as a coherent framework for analysis.
- Does biodiversity in itself have value? Or is it part of a broader system? ESS approach helps frame the debate.
- One area of research: understand impacts of LUC on ESS
- Research challenge: measurement & quantification (economic terms, physical terms)

- Quantification of consequences of particular intervention in terms of costs and benefits (ESS, etc.) Important to have toolkits that help decision making
- Existing tools – RSPB has been collaborating on development of one. Bangor University developing tool. But currently none implemented.
- How do you make consistent value judgements?
- Not just land use issue, it's a resources issue, and trade-offs associated with decisions.
- Need to define what a sustainable LU is for a particular landscape
- Need to consider economy wide impacts of LUC.
- Policy decision how do they affect LU nationally directly and indirectly?
- Economics to encompass green GDP indicators, not just conventional GDP
- Do we have models of sustainable land use?
- Boundaries between sustainability and land use? Parcel of land has a resource capacity, environmental (nutrient recycling), economic (value creation), social (job creation – income for people to exist in the landscape)
- No longer deal with economics – distorted by fossil fuel use. Consider energy balances instead. If energy negative, no further considered. If positive, considered & expected to become economically viable eventually.
- Economic valuation should be based on a virtual currency, ie carbon, energy balance, nutrients, not linked to real world money
- Sustainability also brings into it technology and resources use (water, nutrients, etc). To make BE you need inputs, not just sun.
- Sustainability – can we agree of what it means and is there a substitutability aspect? Maximising resource use, also in terms of waste utilisation (most waste of biomass origin). Fugitive emissions of landfills approx. 30-40% -> huge impact. AD leakage approx. 1 % acceptable level
- How do we make the circular economy work properly? Traditionally farming practices vs resource reuse. How do we make system sustainable in terms of resources input? Develop toolkits of broader system boundaries and inputs-outputs. Full system analysis. Different toolkit from LCA methodology.
- Full system analysis – entire value chain, prior to consumption. But also broader impacts on supporting system, including carbon stocks, nutrient balances, water balances, etc. What are the net inputs? Chain as a whole has to be sustainable, unsustainability in one stage can be offset at other stages of chain.
- CCC biomass potential – UK land potential vs global potential for bioenergy.
- Optimum use of biomass – conversion issue?
- What is the potential on UK biomass for energy at the moment (baseline)?
- It takes time to bring energy systems online. Need to be aware of timescales when making predictions.
- Land management without prejudicing future operations. Consider land in terms of biggest energy potential per ha & energy balance. Gets around issue of food vs fuel. But then how do you quantify other ESS impacts?
- Multi-criteria optimisation models – final value of fuel, not just in terms of energy value. Do we need to consider biomass as future renewable carbon source of future?
- RELU (?) project – ranking of biomass feedstocks in terms of energy potential. But then what is happening to biodiversity and other ESS.
- Are there sufficiently large GHG savings in production system? And what are other environmental impacts.
- Need tools (robust, consistent) to inform policy and market. What parameters should go into the model? Assessment system that is flexible.

- Screening tool for sensible bioenergy policies and incentives.
- What are the drivers? DECC, etc needs answers now.
- Why do we need to consider land use at all? Should we instead just focus on waste biomass? Manure, food waste (in-field, post-consumer, processing), crop waste, etc. But current focus is on land availability and land based biomass.
- Full system analysis of waste fuelled bioenergy systems to avoid virgin inputs into system, eg maize silage for AD
- Defensible whole system analysis of the global bioenergy production system – global whole system analysis. Consider spatial scales and temporal scales.

Flipchart notes:

- Land use = resource use
- What are transition implications, eg, for ecosystem services, metrics, how to asses in a conceptual way (transitional issues)
- Research challenge (economic) – models that account for resource (water, land, biodiversity) use
- Levels – farm, catchment, economy
- Timescale
- Research question: quantification of the system (eg, energy balance)
- "Toolkits" – how do we augment existing models & frameworks
- Overcome terminology barriers (sustainability)
- Understand – early on – system fundamentals. Eg, how much available energy in 1 kg wheat straw
- Objective: whole system analysis – how do you know whether it's "good"? Target: whole system analysis at global scale
- What is waste, should we focus on individual, more "attractive" wastes?
- Food waste, manure, vegetable processing, etc

Annex C: Cross-community discussions - Deep Dive 2

C.1 Group 1

Main Research Challenges

What's worth doing, and what isn't? What do public, politicians etc consider important, and what do they understand by bioenergy? Where does public perception matter? Need to understand the 'pinch points' at which the public will get involved/worried by developments – economic, GM etc. Often a confusion of messages, a lack of coherence in public messages and information. Biomass fears come from food riots, worries about food-producing land being used for energy, lack of belief in climate change. How can we apply existing knowledge to explain the issues? How do scientists communicate uncertainties to the public? The sceptical side deal in absolutes.

What are the levers and mechanisms that can be employed to have a positive effect on public perception to influence social acceptability?

Tradeoffs, economics, options, the absolute cost of emitting CO_2 and causing global warming. Government understands and deals in economics and figures. Terms – need to explain to the public the problems with refusing a piece of technology and the possible implications for their lives. What mechanisms will encourage and promote social acceptability? Thinking about windfarm community acceptance – similar idea for bioenergy incentives? 'If you can see it, you'll benefit from it' in the form of incentives. Need new thinking about incentives. – communicating negatives as tradeoffs.

How do you balance out the different tradeoffs required in a system, how do you weight them and how do you explain that weighting to the public? The use of social media to inform the public – very important to engage. Children also need to be educated in school – from primary school onwards. Undergraduate level particularly important to get people to work in bioenergy at PhD level onwards. Maybe more knowledge exchange and public engagement than basic research. Need some good social scientists who can understand the physical science, and its limitations and barriers. Need to be careful not to take a 'Stalinist' approach, and engage rather than direct. Gross national happiness instead of GDP?

What are the mechanisms that allow you to make 'evidence-based' tradeoffs, rather than tradeoffs based on personal investment (vested interests). A similar system to NICE (NHS) could be developed – objective policy assessment tool, allowing an objective, evidence-based examination. What Works Initiative. Public-facing and open. Ensuring it's populated with the right scientific evidence. Accepted by Cabinet Office etc. ESRC call happening along these lines. What funding bodies would need to collaborate? Probably all the RCs. DECC, DEFRA, BIS, maybe FCO. Need upfront the acceptance that there can and will be outcomes from this tool that people will not like. Recognise that you may need to 'fight the battle' at multiple levels – national, local, regional. May need to reframe message and use different mechanisms.

How can we break barriers between social and natural scientists, and indeed between social scientists, given the breadth of terminology and processes that they use. How to embed interdisciplinarity? Learn from RELU. Tell them they have to work interdisciplinarily in order to get funds. A decent percentage of funding should be allocated for interdisciplinary projects. Shared skills and learning. National Centre for Research Methods for social scientists exists – roll out for other disciplines e.g crop scientists?

What do we need to have in place?

Interdisp. funding as soon as possible. Enable organic growth of interdisp working. This can't be forced! Associated studentships and training. A wider change in philosophy regarding single versus interdisp research. Flexibility – ability change/shift focus during a research project. A longer term continuity of funding – see UKERC, which is getting a phase 3 renewal. Bioenergy is a relatively new discipline and needs long term support. Changing opinions, attitudes and beliefs takes time. Needs commitment and consistency – leading to trust. Interdisciplinary Assessment Panel for responsive mode schemes.

C.2 Group 2

Supply Chain Logistics

- What is the bioenergy potential of remote regions?
- Right crop/right location for end use
- Logistics R&D for UK Application
- How do we transport biomass economically?
- Storage and handling of biomass fuels
- Biomass as a carbon sink
- Improve efficiency
- Research into agricultural machinery

Divide by transport mode or by sector?

- Start by looking at large volumes of pellets and understanding constraints in port and rail sectors
    - Enabling port operators to have pellet-appropriate infrastructure (e.g. fire prevention, dust mgmt techniques, pellet storage facilities) is quite a challenge
        Optimum fuel storage : reduced capital cost requirements and improved safety requirements
    - Three main freight operating companies running in the UK
        - Wagons designed for coal, and not suitable for biomass. Can either redesign the wagon, or cover the existing wagons
        - Make wagons more pellet appropriate?
            - Could potential have more volume with fewer deliveries
        - Little research in the developments in these areas > using materials science, construction engineering depts, + architecture and product design
        - Existing research predominantly focussed on coal conversions
    - Feedstock predominantly from NA and Canada
        - Utilising residues that don't normally have a market, but some examples of diverting from existing industries

Rail

- Wagon design
- Scheduling issues with accessing sufficient rail paths
- Better signalling systems and IT systems would allow for more efficient scheduling
- Least-cost networks

Road

- Hard to get all the things that need to be converted in one place at one time

- Wissington > a truck every 30s for 9months a year?
- British Sugar has agricultural logistics down to a fine art (e.g. BP/BS partnership)
- Often use cheapest available technologies
    - e.g. tractor and a trailer, or just a basic truck?
- Small scale chip deliveries are slightly different
- Need to bring together designs of the dumpers with the designs of the stores

Sea

- Trans-atlantic shipping
    - Design of ship offloading technology
    - Focus on developing new technologies as well as adaptation of existing stuff
    - Improving both container and hull design for biomass
        - Some work being done in the Netherlands on this
    - Port design also comes into this
    - Weather unloading is a problem for the UK (can't unload with high winds or if its raining)
- Not aware of much research going on into this area

Canals

- Barges carrying biomass?
- But slow mode of transport
- Scenario planning for this perhaps?
- Densification of biomass before it gets onto a vehicle
- Removing water and air
- Assume that water and air have already been largely removed
- Is there no challenge in moving liquids around? As oil companies already have this covered?
    - Bioethanol has a corrosion factor, but assumed largely to have been solved

Do you look at transport in isolation of location?

- Ports and arable land towards the East of the UK
- Spatial mapping could be a topic in itself
- Optimum designs for biomass infrastructure networks
- Scenario modelling
- Give it to industry who could either use or ignore it.

Storage

- Dust control
    - Fundamentally quite different from chemical dust
    - Falls under ATECH's regulations
    - What could a PhD student research on this?
        - The key differences between biomass and chemical dust?
    - Quality assurance is broadly determined in the pellet mill, and can change dust characteristics
    - Monitoring/prediction and modelling technologies
    - Dust suppression vs. dust management
        - Optimum techniques specifically for biomass dust

- Hazard control re: fire/self-combustion
    - CO accumulation at pellet stores
- Training of staff and operatives
- Longevity issues with bugs, damp
  - Consequences of long-term storage
  - Pre-storage preservation of biomass pellets?
- Water absorption (e.g. ethanol) and microbial growth in liquid biofuels
  - Similar point with pre-storage preservation needs for bioliquids
  - Biodiesel goes off horribly
  - Computational fluid dynamics and viscosities for bioliquids
  - A lot of this work has probably already been done as large int'l markets already exist
- Handling
  - Optimising conveyor design
  - Dust accumulates on the cogs

    Handling technologies > is this unique to biomass?
    - Or a case of knowledge transfer from other materials, towards biomass
  - All very bespoke to one feedstock > but if every feedstock was pellets wouldn't be too different
  - But could design more flexible systems > e.g. systems for chips and pellets
  - Currently use grabs/claims to move pellets in ports
  - Vacuum cleaner for pellets deliveries?
    - Could look at larger scale applications of pneumatic blow/suck technologies
- e.g. Wolfson centre for solid handling
- Building design could be an issue
  - One of the biggest contributors to CAPEX in new projects
  - Need as much storage as possible to offset supply chain risks
  - Reducing CAPEX through intelligent building design?
- Room for large 'Amazon' style hubs / warehouses
  - Commercial issue, but also potentially researchable

Infrastructure

- Intelligent building design
  - Design of blending stations (across liquids and solids)

Who is best placed to design this research?

- Academics win a research project and then employ people to do the research
- Collaborative research between industry/TSB/RC and academia
  - EPSRC?
    - Most of this would fall into this remit
  - BBSRC
    - Biomass modelling and storage could fall under their domain...
- Universities would get involved in this assuming there was sufficient money in it
  - Spatial planning could be quite an interesting subject for academics ... ESRC ?
  - A lot of emphasis on interdisciplinary approaches, so have a better chance of winning cross-council programs. Is this something that universities should be doing?
    - Should the RCs make this a condition of funding. This would be realistic.

  - Location aspect of UK production and of imported goods
  - Or storage at generation points

How to do it?

- Does it have to be between research funds?
  - Could it be KTN?
- RCUK energy could launch its own funding calls? Rather than having to go through other bodies. like LWEC (Living With Environmental Change) does
- Highlight notices (but more for individual rather than joint councils)
- Better mechanisms for councils developing cross-council funding in these areas
- Is it politically better to have joint calls? Although govt. might have problems with these working together.
- Bioenergy is a key area that could have some of these proposed joint calls
  - 'collaborative calls'

Transport fuels

- Split it out by transport mode?
  - But maybe doesn't help in terms of research calls structuring
- Or do you want to do it by generation?
- Huge issue on the whole waste-to-energy program
  - Which sector gets what?
  - Massive policy void in this area
- Doing by generation might help drill down to specifics

Bioethanol

- How many ways can you make it?
- Biomass component of municipal waste?

First generation transport fuels

- Should focus on liquid end products (or potentially gases)
- Will need liquid fuels for some time to come because of the Internal Combustion Engine
  - Still need shipping and aviation, but this is second generation biofuels
  - Need to focus on first generation if electrification happens?

Non-food crop-based liquid fuels

- How to convert biomass to fuels? This is 'one-step to liquid'
  - Bioenergy crops
  - Algae
  - Waste straw
    - Enzyme degradation then fermentation to release sugar in straw and turn this into a fuel (enzymes are expensive)
    - Could also pyrolyse it
    - Or gasify it into bio SNG

    - Municipal solid waste
    - Perennial bioenergy crops
    - Food waste
    - Wood
    - Grasses

Also need to address research challenges for conversion technologies

- AD?
- Other deep dives focusing on pyrolisis/gasification ?
    - Assumed that they are including pre-treatment in this discussion. Flagged as a big research area that may not be able to be covered by the expertise in this room.
- This deep dive focussing more on products of conversion technologies?

Post-processing and upgrading

- Biodiesel needs to look exactly the same as diesel
- Bio SNG?
- Challenge is to make the above feedstocks into 'drop-in' fuels, so as to not have to redesign existing engines
    - Blend
        - Need to blend different outputs from algae based fuel?
    - Drop-in
    - Novel - is there a 'new' category on bio?
        - Unsure as to whether there is anything in this domain
- Scale up of all of these is an issue
- Regulation
- Consistency and homogeneity
- Purification and water removal
- Additives to negate negative characteristics
    - Improve fuel quality

Hard to determine research challenges in this area, as perhaps too broad?

More of a series of research challenges with each of these inputs, and converting it into an appropriate end-use fuel.

Fuel vs. food argument

- ILUC and GHG arguments against bioenergy?

Challenge is that need to find a % of 40m tonnes of liquid fuel.

- Policy has moved too far ahead in terms of commercialisation?
- Oil seed rape productivity has increased 25% as a direct result of investment
- Massive gains to be had in productivity terms, but getting into land use issues here.
- Massive problem in the subsidy regime
- Getting these plants operating effectively at scale is an issue (but perhaps not an academic research challenge?)
- Anything to research in infrastructure
    - e.g. implications of higher proportions of biogas on the network.

Aviation

- Has to be a 'drop-in' lighter fraction fuel à la Kerosene
    - Fluid dynamics, as will have a different effect on the engine
    - Combustion engineering
    - Must be liquid > fuel sensitivities of jet engines
    - Food crops are a no-go
    - Algae?
- How do you actually prove viability of fuels in aviation?
- More of an equipment issue > finding ways of practically testing these fuels?
- How safe is it?
- A phone call to industry would help to clarify this issue ... and if there is any point in researching this? e.g. Rolls Royce might just say no
- Ground-handling issues
- Fuel distribution issues?
    - Similar to previously mentioned fuel storage for liquids issues

Shipping

- How can we go on using bunker fuels with impunity?
- Currently using diesel
    - Potential for biodiesel
    - Could use LPG >> room for biogas? Probably not. *(REA argues LPG not bio and therefore should be removed)*
- Equivalence
    - More scope to 'go wrong' as it's in the sea not in the air
- Ethanol to diesel? ED90? Possible application within the diesel sector?
    - Engines are pretty flexible so wouldn't necessarily have to be identical
    - Long-term storage of biodiesel is an issue though
- Algae producing diesel?
- Waste oil for shipping use?
- Pyrolysis oils? Hard to burn...horrible stuff. Highly acidic.
- Room to work on efficiencies > but beyond the bio issue

Rail

- -Electrification would seem to be the most viable option
- -Bioenergy > electricity > trains
- -Algae or non-food crops?
    - Getropha? other diesel like crops?
- Need to investigate viability of biodiesel?
- Combustion issues?
- Research into tolerances of existing rail engines
- Lifetime / maintenance requirements
- Fuel distribution
- Health and safety implications
- Engine design

Public transport

- Trade a bag of food waste for a top-up on your Oyster card?
- Biogas is a big one here

Road

- Ethanol/biodiesel/biobutanol/biogas
- Blending limits in terms of ethanol
- Assuming no engine design?
    - Car companies will produce what the market wants
    - Happy to provide this in Brazil, so not a research topic
- Microbial fuel cells?
- Economics of building biogas networks?
    - Or converting the existing network to biogas
- Spatial distribution of AD facilities in relation to transport networks
- Efficiency limits of anaerobic digestion?
- A lot of this (e.g. Biobutanol - Dupont research) is being covered already in a commercial sphere
- Toxicity in biosystems could be a big problem > affects yields
    - Potential research topic?
- Barriers to the uptake of liquid fuels are policy rather than research?
    - Has the policy stopped it so soon that the research couldn't get far enough
    - Or is the case that oil is too cheap, and therefore investment in biofuel research has been limited
    - Is it a case of market failure in biofuels? Need govt. support?
- Has to be a political decision whether we continue to use FF in the transport sector?
    - Or are they hoping that scientists will make it cheaper enough
    - Does cap on volume restrict research? Or do academics not think this way?
- Money available would be best spent on pure applied science
    - e.g. funding for lignocellulose from straw, with the hope of making a breakthrough e.g. improving feedstock quality
- Southampton and BIZBEC working on this

C.3 Group 3

Research Challenges

- Thermal side - too applied and not thinking enough about fundamental processes. But better catalyst involves some fundamental.
- Bio side is too fundamental - needs more emphasis on the applied end. Real engineering technic terms. Modify crops to match to end use. Modify to deliver biomass with integrating characteristics.
- What's the bio driver - optimality but what does that mean. MCA and weight different factors? Simple way look at minimise cost or maximise profit. Max yield not necessarily same as max profit.
- Thermal gives you lots of things mixed up. Bio is purer in terms of products.
- Where are the step change disruptive approaches? Mix chemical and biological approaches, process intensification etc.

- Synthetic biological. Metabolic engineering. Syngas fermentation. Disrupters. Integrate speed of thermal process with focus of a biological process. RCs cannot cope with x-council processes.
- Look at thermal, look at biological, look at linkage - but we need first to know why we're doing it. What's the main driver? We haven't agreed why we're doing it.
- Need a balanced panel to look at research bids - not all one RC.
- What are the desirable, characteristics of future fuels?
- Biodiesel blends - you'd re-design the engine and the blend.
- HGV EU rules will not allow current biodiesel to pass.
- Cluster 6 has been incorporated.
- Need to know what conversion process is for - implications for bio refineries.
- Optimisation in terms of fuel flex, carbon cost, yield etc. multiple products challenge.
- RT - synthetic diesel compatible with evolution of cars over next 20 years. Priority over synthetic ethanol, butanol etc.
- De oxygenise alcohols. Hybrid process.
- Canadian study - pyrolysis came out top. Some system analysis needed to see if technologies are robust against different carbon prices. RED directive sets targets for life cycle emissions.
- Fundamental research on catalysts. For yield improvement. But more fundamental research to be done on biochemical in the end.
- Design of future biomass based fuels compatible with future engine technology
- Disruptive step change solutions based on combining research disciplines, e.g. Biology, synthetic biology, chemistry , process engineering, intensive.
- System integration of whatever technology you're looking at.
- Fundamental biosciences, cell walls, accessing sugars etc.
- Thermochemical - main challenge is picking potential winners. Scalability, flexibility, efficiency, sustainability, affordability. Optimise across the system. Load following, stand by, baseload.
- System integration, gasifier scale up.
- Gas clean up - combined thermo and bio processing.
- Feedstock competition potentially. A longer term scalability hurdle. Heat, power, chemicals, material.
- Synthetic biology and metabolic engineering to optimise feedstocks. + conversion organisms and/or enzymes
- Challenges of converting fossil infrastructure to biological.
- Fermentation optimisation , role of inhibitors.
- Process comparison - ethanol
- BioCCS on to Fischer-Tropsch - cost advantage.
- Process/system modelling
- Large scale biomass combustion NOX emissions.
- Understand scalability rather than scale up.
- Scalability is cross cutting, not just specific to gasification.
- Gas clean up - engines, turbines, biofuel synthesis. Large scale stuff.
- Understanding relationships between feedstock, technology, emissions. Pretreatment options.
- Chemicals for processing and conversion of sugars. Different from bio or thermo. Pretreatment followed by processing of sugars. Liquids, acids, catalysts.
- Understanding and manipulating plant chemistry,
- Look at multistage processes, not just final product.
- Algae is embedded within synthetic biology metabolic engineering.

- BioCCS FT is modelling work.
- Thermo is EPSRC, bio is BBSRC, hybrid falls between cracks
- Final details on algae and wet processing - make sure in but don't over-emphasise.
- Hybrid thermo chemical processes hybrid thermal.
- Matching biomass type to reactor type and product.
- Catalysts research works regardless of technical solutions.
- Fossil conversion - how much can you use as is, how can you retrofit optimally.
- Fuel pre-treatment - combustion, generation, gasification. Pyrolysis and torrefaction.

Different funding bodes coordination

- Whole of bioenergy into cross-council programme. But what about crops that provide both materials and energy.
- Add BBSRC type challenge to SUPERGEN Hub?
- Joint thematic area.
- Bioenergy and bio products need to be linked to keep BBSRC happy.
- Solve committee structure problem for double jeopardy.

Training

- Cross discipline training. Interdisciplinary studentships. An initiative in the hybrid space?
- A lot could be added to existing training programmes without going the whole way. How to build in language communication
- Urge for bioenergy committee structure, but admin horror.
- EU performs better because someone owns the themes. Easier to do cross disciplinary.

C.4 Group 4

- More integration of bioenergy with biorefineries to produce higher value added products, substitutes for fossil
- Best use of biomass – flexibility
  - Volume
  - Use (transport, heat, electricity, co-generation

Optimisation & integration

- Optimisation for what?
  - Systems issue – energy / bioeconomy systems perspective
  - Optimise and integrate around that
  - Similar to fossil economy – supply chain of crude oil to multitude of products of which energy is only one
- Best use of biomass for end use
- Technology matching
- Biorefinery as implementation tool of bioeconomy. Biomass for carbon.
- Carbon as unit of analysis – where could it go
- If this is about biorefining, what processes are needed. Need to know what products are and understand fractionation for given products.
- Optimise for most efficient route to products
- Inefficiencies in system. Prioritise around efficiencies. Neglects demand focus. Need demand focus.
- Flexibility in biorefining for different products

- Main research challenges:
    - Cost-reduction / cost-effectiveness – cost effective production of bio-products, incl energy
    - Relative vs absolute GHG savings (counterfactual: fossil substitute)
    - Substitution of fossil fuels
    - What are the modules and what are the linkages? How can these be integrated / optimised?
- Considerations:
    - Economies of scale
    - Cost of carbon

Risks / flexibility / security

- Security of supply
- Seasonality of supply
- Risk mitigation
- Flexibility & adaptability to circumstances & environment
- Understanding the risks of investing / switching to BE crops
- Flexibility & security of supply
- Residue utilisation
- Continuity & security of supply
- Impact of extreme weather events (disruptive climate change)
- Improving fuel quality through pre-treatment & densification processes (palletisation, torrefaction, washing) to allow access to a wider range of feedstocks for large scale power generation
- Upgrade of biomass as feedstock (improved quality, storability, transportation, homogeneity) through pre-treatment & densification processes to allow flexibility of biomass use (make use of wider range of biomass types)
- Quality & flexibility of biomass use
    - Pre-treatment technologies for homogeneity (quality, size, texture)
    - Feedstock flexible technologies
    - Scale (infrastructure, logistics, efficiency, cost)
    - Storability & transportation (degradation of product)

Discussion:

Research questions:
- Not about biorefineries any more
- Lots of spatial components:
    - International supply chains – understand where feedstocks come from internationally
    - Deployment of technologies
- Security of supply
    - Make imports as economically as possible
    - Impacts of supply chain disruption, eg disruptive climate change
    - Geo-techno-political analysis
    - Flexibility and adaptability of operations, eg power stations
- Logistics:
    - What is needed in terms of pre-treatment of feedstocks to make it suitable (eg Drax pre-treatment of willow)
- Contingencies
    - Eg Drax building ports in US for biomass shipping, buy forests in US (power station is optimised)
- How far do you go with your flexibility of supply as opposed to other GHG mitigation measures, eg increase efficiency of operations
- Trade-off between efficiency optimisation and feedstock flexibility. Understand ranges.
- What is the tolerance of a biomass burner – how much flexibility is there? And how much variability is there in the feedstock? How do you optimise your operations accordingly?

- Better to grow mixed woodland for bioenergy production (better biodiversity, etc), but problems in energy conversion because of different species. Is torrefaction the answer? Will it improve homogeneity of feedstock? Design boilers to tolerate specific ranges of feedstock variability. Is there a consistent uniform fuel?
- Novelty:
    - homogeneity of variety of feedstocks
    - What new processes / materials are needed for conversion to become more efficient?
- Trade-off of optimisation to allow for feedstock flexibility and security of supply. Diversify demand side technologies.
- Development of intermediaries (technologies) that allow feedstock flexibility (and substitution) to augment security of supply. Counters argument of feedstock matching.
- Need to understand level of variability within feedstocks for your operations

- **Who is best placed to undertake this research?**
    - Who should be involved in developing the solutions?
        - Industry & research community collaboration
    - Collaboration between RCUK & TSB

- **What needs to be in place?**
    - All the items listed in guidance notes (discussion questions)
    - Better insight in industry – get academics more closely involved with industry. People & knowledge movement mechanisms. People & information sharing.
    - Access to information by all stakeholders
    - Understanding of risks and failures by feedstock (eg weather events)
    - Integrated knowledge
    - Understand geo-political aspects of feedstock procurement – should it be on the political radar?
        - Economics
        - Politics
    - Risks associated to meeting sustainability criteria of biomass feedstocks – but should this be focus of RC research? Probably not.
        - Businesses
        - Governments

- **Funding philosophy:**
    - Data platforms to share information & knowledge – allocate funding to development
    - Feedstock & conversion technology development should allocate funding to integration of flexible intermediaries

Feedstock adapations
- Larger & longer field trials to understand geographic and impacts of climate variability on feedstocks
- Potential markets & feedstocks could be outside of UK (eg rice straw)
- Room for "funky calls" on feedstock development

Develop novel technologies

(2B)

- Developing novel technologies by:
    - Synthetic biology
    - Hybrid bio/thermo processing
    - CO_2 conversion
    - Artificial photosynthesis
    - Use of lignin
- Integration of bio & thermo processing, hybrid processing

- Cost-effective ways of utilising lignin
- Application of synthetic biology to generate novel classes for bioconversion
- Artificial or man-made photo-synthesis
- How to convert CO_2 to valuable chemicals
- Continue fundamental research into LC breakdown and sugar and lignin processing

Novel solutions

(2A)

- Opening innovation to all possibilities (not being prescriptive)
- How will be respond to new technologies and the opportunities that they present, eg synthetic biology
- Are there any geo-engineering synergies with bioenergy production which can be exploited, new area of research (eg albedo)
- Have we captured all the energy we can from the sun? Use more C4 plant species
- Bioluminescent lights

Novel production organisms

(14)

- Algae (macro & micro)
- Fungi that produce biodiesel
- Time horizon for algae energy?
- Algae & other new bio-resources
    - Niche
    - Significant player

Discussion:

- **Research questions:**
    - Is the UK well placed to produce / utilise algae in the first place? Macro vs micro? Applications – focus on high value uses, not bioenergy. Eg algal hydrogen production (Imperial College)
    - Novel conversion technologies?
    - Geo-engineering – sits in RC remits, too many unknowns, but strategically important & must be considered.
        - Forestry form of geo-engineering – value of carbon in standing forests vs alternative uses
        - Synergies bioenergy crops & improve reflectivity / albedo, heat absorption
    - GM as a technique to increase plant solar radiation conversion
    - Strategic optionality
    - Biological CCS – partitioning pre- or post-combustion? Take it out of the atmosphere?

- **Who is best placed to undertake this research?**
    - Academic space

- **What needs to be in place?**
    - Horizon scanning and keep open to novel proposals across RCs
    - RC structure is self-defeating

- **Funding philosophy:**
    - Alignment of different funding mechanisms needed

Annex D: Agenda

Tuesday 14th May	
10.15	Arrival and Registration
10.30	**Session One:** ***Introduction*** Introduction to the purpose and process of this Expert Workshop and the overall development plan to create an Energy Research and Training Prospectus
	Discussions and activities to share current thinking about the current research and research strategy for this sector.
12.15	Lunch
13.15	**Session Two:** ***Exploring the Research Themes*** Discussions and activities to identify and develop potential research themes from different perspectives
	Session Three: ***Reflection and Summary*** Activities to reflect on the various different emerging research themes and their relationships
17.30	Close
19.00	Drinks Reception and Dinner
Wednesday 15th May	
9.15	**Session One:** ***Introduction to Day Two***
	Session Two: ***Deeper Analysis of the Emergent Research Themes*** Discussions and activities to explore emergent research themes more deeply, with the aim of identifying drivers and barriers to these different future research themes
12.15	Lunch
13.15	**Session Three:** ***Further Development of Research Themes*** Discussion and activities to further shape the prospectus
	Session Four: ***Summary and Next Steps*** Plenary session to summarise and discuss the key outputs of the workshop, as well as the next steps in the development of the prospectus
16.00	Event Finishes

Annex E: Participant List

Charles	Banks	University of Southampton
Ausilio	Bauen	Imperial College London
Christine	Bell	Centre for Facilitation
Michael	Booth	Biotechnology and Biological Sciences Research Council (BBSRC)
Tony	Bridgwater	Aston University
Nigel	Chapman	Centre for Facilitation
Steve	Croxton	E.ON
Leilani	Darvell	University of Leeds
Ian	Donnison	Aberystwyth University
Duncan	Eggar	Biotechnology and Biological Sciences Research Council (BBSRC)
Jon	Finch	Centre for Ecology and Hydrology (CEH)
Merlin	Goldman	Technology Strategy Board (TSB)
Benedict	Gove	Royal Society for the Protection of Birds (RSPB)
Kate	Hamer	Biotechnology and Biological Sciences Research Council (BBSRC)
Astley	Hastings	University of Aberdeen
Mike	Hemsley	Notetaker, Imperial College London
Nicole	Kalas	Notetaker, Imperial College London
Iris	Kammerer	Energy Strategy Fellowship Team
Angela	Karp	Rothamsted Research
Fiona	McDermott	The National Non-Food Crops Centre (NNFCC)
James	Mills	National Farmers' Union (NFU)
Geraldine	Newton-Cross	Energy Technologies Institute (ETI)
Stephen	Ramsden	University of Nottingham
Aidan	Rhodes	Energy Strategy Fellowship Team
Jim	Skea	Energy Strategy Fellowship Team
George	Stammers	Dalkia Bio Energy
Peter	Stephenson	The Economic and Social Research Council (ESRC)
Greg	Tucker	University of Nottingham
Sarah	Ulliott	Department of Energy & Climate Change (DECC)
Claire	Wenner	Renewable Energy Association (REA)
Mark	Workman	Energy Research Partnership (ERP)