Biotechnology and Biological Sciences Research Council Sustainable Bioenergy Centre (BSBEC)

Nuffield Council on Bioethics
Consultation Document on
New Approaches to Biofuels

RESPONSE FROM THE BBSRC SUSTAINABLE BIOENERGY CENTRE (BSBEC)

BACKGROUND

1. BBSRC[1] is the UK's principal funder of basic and strategic bioscience. BBSRC conducted a review of Bioenergy Research in 2005-2006 culminating in a report published in March 2006[2]. In this report a view was expressed that "bioenergy has an important role to play as part of a multi-faceted low-carbon solution for the UK's future energy needs". The term bioenergy was used to encompass electricity, heat or transport fuels derived from renewable (non-fossil) biological sources: typically the combustion of fresh or processed (solid, liquefied or gasified) biomass or, potentially, electricity generation through redox reactions in microbial fuel cells. The report concluded that BBSRC has a unique role to play in supporting "basic and enabling bioscience for bioenergy". It noted that research into societal issues and public engagement around bioenergy should also be part of the remit of funding so that broader aspirations and concerns are understood.

2. Within the UK Research Councils' Energy Programme, BBSRC is now providing a major focus on Bioenergy, specifically biofuels for transport, through the BBSRC Sustainable Bioenergy Centre (BSBEC). Launched in 2009 for a period of 5 years, this Centre delivers integrated activity across 6 research programmes that bring together a total of 12 universities and institutes with 14 industrial partners.

3. So far, biodiesel has accounted for much of industrial-scale production of biofuel to meet the Renewables Transport Fuel Obligation (RTFO). This is largely due to the simple conversion technology needed for biodiesel production and the relative ease of using existing infrastructure. However, it is generally recognised that biodiesel production does not represent an efficient use of land and the GHG mitigation of this fuel is less positive than might be achieved by other methods.

4. It is also widely recognised in the UK and internationally that 'first-generation' biofuels may have significant negative side-effects in terms of competition with food production, loss of biodiversity and, in some cases, increases in CO_2 emissions caused by changes in land use. BSBEC was created to focus specifically on researching 'second-generation' approaches to biofuels that may offer more sustainable ways of generating energy from biomass, thus providing low-carbon alternatives to fossil fuels without damaging food security or the environment.

5. BSBEC draws on expertise and resources in crop, plant, microbial, cell wall, fermentation and biochemical sciences from leading academic and industrial organisations. The science partnership

[1] Biotechnology and Biological Sciences Research Council (BBSRC), a non-departmental public body, is one of seven Research Councils supported through the Science and Innovation Group of the Department for Innovation, Universities and Skills (DIUS). BBSRC works with partner Research Councils through RCUK.
[2] Report available at http://www.bbsrc.ac.uk/web/FILES/Reviews/0603_bioenergy.pdf#search=%22Bioenergy%22

(Table 1) comprises six “Programmes”, each led by a Principal Investigator (PI) with internationally recognised expertise in their respective fields. Further details can be found at http://www.bsbec.bbsrc.ac.uk

Table 1: Participating organisations in the six programmes of BSBEC

Programme	Partner organisations
P1 Perennial Bioenergy Crops Programme	Rothamsted Research (Leading) Institute for Biological, Environmental and Rural Sciences (IBERS) Imperial College University of Cambridge Ceres Inc.
P2 Cell Wall Sugars Programme	University of Cambridge (Leading) Newcastle University Novozymes
P3 Cell Wall Lignin Programme	University of Dundee (Leading) University of York SCRI RERAD Advanta-Nickersons Syngenta
P4 Lignocellulosic Conversion to Bioethanol Programme (LACE)	University of Nottingham (Leading) University of Bath University of Surrey BP Bioethanol Limited Briggs of Burton British Sugar Limited Coors Brewers Limited DSM Ethanol Technology Limited HGCA Pursuit Dynamics SABMiller Scottish Whisky Research Institute
P5 Second Generation, Sustainable, Bacterial Biofuels Programme	University of Nottingham (Leading) Newcastle University TMO Renewables Ltd
P6 Marine Wood Borer Enzyme Discovery Programme	University of York (Leading) University of Portsmouth Syngenta Biomass Traits Group

6. The BBSRC Sustainable Bioenergy Centre (BSBEC) will focus on four key challenges that are central to the establishment of sustainable alternatives to fossil fuels. These are: sustainability (in environmental/energy, economic and social terms), development of appropriate feedstocks, study of cell walls to improve yield, and conversion to biofuels. The embedding of social science and ethical analysis in the LACE programme is particularly novel and is intended to enable ongoing engagement with wider societal and ethical issues.

7. The following is a collective response from the scientists who are leading the six programmes of the BBSRC Sustainable Bioenergy Centre (BSBEC) listed above. While closely aligned, it does not necessarily represent the views of the scientists’ parent institutions or of the BBSRC.

RESPONSES TO INDIVIDUAL QUESTIONS

Question 1. What is your view on society moving towards greater use of biofuels?
Our view is positive, as long as fuels used have been subjected to rigorous life-cycle analysis (LCA), have positive energy balance and significant GHG savings and are resourced in ways that are environmentally and socially sustainable, including paying due attention for the need for land to be used for food production as a primary purpose of agricultural land activity.
In order to meet the EU's legally-binding target of 15% for renewable sources in the energy mix by 2020, the UK government has set a goal of 10% for renewables in the transport sector (currently, it is less than 3%). At present, biofuels are the only realistic renewable carbon-based liquid fuel alternative to fossil fuels. Some transport will require carbon-based liquid fuels for the foreseeable future, i.e., air, sea, HGVs. Second-generation biofuels could make a substantial contribution to the UK's energy targets and to the global response to climate change as part of a mix of alternative transport fuels combined with energy demand reduction. To ensure that this promise is fully and openly explored, close attention must be paid to the technical choices, and social and institutional arrangements through which biofuels would be introduced and to their potential ethical implications. This is a core aspiration of BSBEC as described in our cover statement. Public engagement around the wider issues raised by biofuels is also important so that there is an opportunity for greater understanding of and dialogue between different concerns and priorities.

Question 2. What are the most important ethical challenges raised by the prospect of future generation biofuels?
A key challenge for biofuels in general is the limited availability of biomass and land, with a multiplicity of needs including food, feed, platform chemicals and energy generation. Related to this is the drive to indirect land-use change in some parts of the world as in the widely cited cases of biofuel plantations being responsible for deforestation. The water footprint of biofuels is also a key issue that is beginning to be recognised. Second-generation biofuels offer the prospect of limiting some of these problems. For example, in the UK, perennial biomass crops (short rotation coppice willow and Miscanthus) could be grown for energy purposes on sub-prime arable land to reduce the competition with food production (Karp et al 2010).[2] Although many of the implications could be positive as the RELU-Biomass project demonstrated and as seen in this paper, it is important to explore the range of consequences more fully.[3]
Lignocellulosic conversion could also use feedstocks that are agricultural residues (wheat and barley straw), thereby improving the profitability of food production and increasing overall GHG savings. However, there are trade-offs that will need to be considered. For example, conversion of large areas of land to SRC willow and Miscanthus could constitute a major land-use change with implications for the appearance of the rural landscape, tourist income, farm income, hydrology and biodiversity (Karp et al 2010). Second, potential competition between use of residues for biofuels as opposed to other purposes including heat and power generation where efficiencies are higher will need to be explored (Gallagher 2008).[4] Third, residues have in situ value as organic material for soil fertility and conditioning, and the impact of removing them needs to be properly understood and managed in specific situations (AEA Technology for DEFRA 2008, p.32).[5] The same report suggests that there is good practice guidance in the USA and Europe to ensure that some organic matter is left in the soil, although their implications for particular projects must be explored.
In general, the overriding consideration when faced with concerns over global food security is the impact of biofuel production on reducing land available for food production. If current incentives change under increasing demand for biofuels and make the price of biomass feedstocks competitive with grain prices, higher quality arable land may be converted to energy crops, thus increasing the conflict between food and fuel (Lovett et al 2009).[6] If these feedstocks are grown at the expense of food in developing countries

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[2] Karp A. et al. (2010). Perennial energy crops: Implications and potential. *What is land for? The food, fuel and climate change debate*. M.Lobley and M.Winter. London, Earthscan
[3] http://www.relu-biomass.org.uk/
[4] Gallagher, E. (2008). "Review of the Indirect Effects of Biofuels. Renewable Fuels Agency." from www.dft.gov.uk/rfa/reportsandpublications/reviewoftheindirecteffectsofbiofuels/executivesummary.cfm
[5] DEFRA (2008). Review of work on the environmental sustainability of international biofuels production and use: A report by AEA Technology plc., Department of Environment, Food and Rural Affairs
[6] Lovett, A.A. et al (2000). Land Use Implications of Increased Biomass Production Identified by GIS-Based Suitability and Yield Mapping for Miscanthus in England. *Bioenerg. Res*. DOI 10.1007/s12155-008-9030-x

and subsequently exported for fuel consumption in the UK, there is a further ethical dilemma. Second-generation technologies will therefore need to be applied and managed in a way that is responsive to these challenges.

It is also important to recognise that the ethical debate around biofuels needs to be framed in terms of potential benefits as well as harms and both must be explored more fully. For example, what are the ethical assumptions embedded in the current regime? What are the ethical implications of not adopting biofuels? These questions must be considered alongside the problems and challenges.

Question 3. Do you regard yourself as well informed about biofuels? Where do you get your information from?

This is a collective response from the scientists who are leading the six programmes of research in the BBSRC Sustainable Bioenergy Centre (BSBEC). As academics studying the growth and properties of biomass for biofuels, we are involved in producing scientific publications, presenting at academic conferences, and engaging with stakeholders including industry, governmental organisations, funding bodies and NGOs. We obtain our information from these interactions, the scientific literature and our own work. In the time leading up to this response, we have engaged in discussion around some of these questions with colleagues in disciplines other than our own, including economists and social scientists. We do not, however, claim to be experts in all aspects relating to biofuels.

Question 4. Which factors are going to be the most important in driving the development of biofuels in the future? To what policy concerns should priority be given? What advantages not mentioned here could and should future biofuel production aim to deliver?

The major drivers will be national and EU policies, and factors that are amenable to policy intervention, namely, price and availability of feedstocks, and GHG savings. Policies must be targeted towards achieving sustainability across the whole supply chain, security of feedstock supply and creating a stable system of incentives and regulation. Gallagher (2008) observes that a genuinely sustainable biofuels industry is possible if policies are developed to encourage biofuels which avoid indirect land-use change. The risks of iLUC can be significantly reduced by ensuring that feedstock production for biofuels takes place on idle/marginal land and by encouraging the use of appropriate wastes and residues (Gallagher 2008, p. 41).

Potential advantages in addition to climate and energy security are a source of income for farmers, and potential efficiencies from the development of simple dual-use crops (i.e. seed used for food/feed and straw for biofuels). Even greater benefits may come from developing the more sophisticated concept of a biorefinery, e.g., where plant biomass could deliver sugars/oils for fuel, and protein for feed while lignin in lignocellullosic biomass could be the basis for platform chemical production.

Question 5. Which of the new approaches to biofuels will be most successful in generating GHG emission savings? How should these be encouraged? Are there any reasons why these new approaches should not be encouraged?

It is not possible to authoritatively predict at present which of the new approaches will be most successful. Not enough data exists at present; research is currently underway in BSBEC and other units to explore the viability of different approaches that are promising. What we can say with confidence for our own area of research is that it is certain that significant improvements and efficiencies can be made at many points in the biomass to biofuel chain. In BSBEC, we are exploring some of the key challenges which need to be addressed to achieve sustainable conversion of lignocellulosic materials to fuels including:

- optimisation of straw and energy crops by maximizing biomass, reducing inputs, and identifying good biomass compositions;
- improving the accessibility and extraction of sugars using enzyme toolkits that can be applied to multiple plant biomass streams;
- exploring techniques for reducing water and energy inputs in the pre-treatment of biomass;
- generating substrates that are “fit for purpose” for fermentation with low inhibitors;
- developing microbial strains that can utilise the sugars liberated and efficiently convert them to fuels (in this case ethanol or butanol);
- optimising fermentation to achieve efficient conversion.

Increasing the efficiency of the process of biofuel production in these ways should significantly improve the GHG savings compared to current estimates, although we cannot predict the magnitude of the improvement.

Our view at present is that only techniques using abundant residues or low input energy crops will make a significant contribution to GHG emission targets. This is because only processes done at a sufficiently large scale will have any impact on GHG savings. So, individual algal bioreactors may give large negative GHG calculations; however, they are collectively unlikely to produce large amounts of fuel and hence will have little impact on GHG targets. Secondly, perennial energy crops such as SRC willow and Miscanthus require lower inputs, and life cycle analysis of fuel chains for these crops indicate higher energy gains and greater GHG reductions than first-generation crops (Rafaschieri et al, 1999; Adler et al, 2007; von Blottnitz and Curran, 2007 cited in Karp et al 2010).

Hillier et al (2009) note some of the conditions necessary for achieving specific levels of savings from bioenergy crops, i.e., crop yield (through its impact on soil carbon inputs and fossil fuel displaced), on crop type (through different yields and conversion routes), and on previous land use (through the relation with soil carbon stocks).[7] They report LCA calculations indicating that replacing grassland or arable land with Miscanthus or short rotation coppice (SRC) crops can yield significant GHG savings. Previous land use is a key factor here, making the difference between positive effects (i.e., from replacing existing arable land) as opposed to neutral or negative effects (i.e., from replacing semi-natural land/forest). Hence, the question of how these 'second-generation' crops are to be introduced into the landscape needs to be carefully considered.

[7] Hillier, J. Et al (2009). Greenhouse gas emissions from four bioenergy crops in England and Wales: Integrating spatial estimates of yield and soil carbon balance in life cycle analyses. *GCB Bioenergy* 1, 267–281, DOI: 10.1111/j.1757-1707.2009.01021.x

Question 6. Which of the new approaches to biofuels will be most successful in improving energy security? How should these be encouraged? Are there any reasons why these new approaches should not be encouraged?

Research is currently underway in BSBEC and other units to explore the viability of different approaches that are promising. In general, we can say that energy security will arise by provision for local production, or diversification of supply. Also, it needs a supply that is sufficient in scale to make an impact. For example, wheat and barley straw could produce sufficient biofuel for 10% of current UK transport use. It is unlikely that any other technology will ever be at that scale in the UK, and therefore such straw is the prime target for development for UK energy security (including in BSBEC research). If a technology were developed for adapting a central processing facility to use a range of residues, then material other than straw could be contemplated.

Another promising approach for energy security (excluding aviation) is the use of anaerobic digestion for producing biogas. The gas can be fed into the grid, can be burned to produce electricity and heat, and can be compressed and used to power cars with only small modification to the engine. It is a simple, well established technology that can make use of a wide range of biomass, waste and dedicated crops, and is ideal for decentralised energy production. Fertiliser is a by-product. There is no reason not to encourage its development.

Question 7. Which of the new approaches to biofuels will be most successful in supporting economic development? How should these be encouraged? Are there any reasons why these new approaches should not be encouraged?

It is again too early to tell without further experience and research. However, it is worth distinguishing between the technology - the 'new approaches' - and policies designed to encourage adoption of 'green' technology generally. From an economic theory perspective, technological change increases output per unit of factors of production – land, labour and capital. This has been a major driver in agriculture's contribution to economic development.

In the UK, economic appraisal of perennial biomass crops has been conducted by the RELU-Biomass project. The picture emerging from this work so far shows both weaknesses and strengths (see Karp et al 2010). On the one hand, biomass production provides less employment than conventional food crops and low returns mean that it is unlikely to be the dominant enterprise on most farms except where the farmer is looking for reduced commitment of time and effort. However, although the commercial attractiveness of biomass crops looked highly questionable in the context of 2007 cereal prices, the situation in the autumn of 2008 looks very different. These findings suggest that policy support is required for a more stable environment and set of incentives for biofuels especially where the environmental benefits are clear.

The agricultural contribution to the economic development of Developing Countries has been particularly important. New approaches to biofuels that sustainably improve the economics or efficiency of agriculture (e.g. dual use of crops for food and fuel) should therefore help support further economic development. Likewise, domestic biofuel production in developing countries, particularly where biomass conversion to fuel occurs in close proximity to biomass production, will create jobs in rural communities. Improved fuel security and reductions in the cost of imports will underpin advances in transport and energy systems in Developing Countries and further support economic development.

As in the UK, new approaches to biofuels should only be encouraged in Developing Countries if they are truly sustainable (economically, socially and environmentally, and in GHG reductions) and do not adversely impact on food security. Biofuel production that does not meet these standards could pose significant risks for developing economies. Appropriate oversight, policies and regulations will be essential to ensuring sustainable biofuel production in Developing Countries.

Question 8. Of all the new approaches to biofuel feedstock development, pre-treatment and processing (including any additional to those mentioned here), which is looking most promising for eventual commercial and sustainable use? Over what timescales might such developments be commercialised? Are there any risks associated with these developments?

Again, it is too early to identify a single biochemical conversion route as there are very many early but competing technologies. Some are likely to be commercialised in the next year or so, and be economic by about 2013/2014. Commercialisation of algal biofuels is likely to take longer.

However, BSBEC clearly believes that 2nd generation biofuels (bioethanol; biobutanol) produced by microbial fermentation from lignocellulosic feedstocks after appropriate pre-treatments, is one of the most promising technologies for sustainable commercial production in the mid- to long-term. We are confident that significant improvements can be made to conversion efficiency at several key stages of the production chain and hope to realise some of these improvements at the research level within the next 1-5 years. There is already considerable industrial interest and investment in the area, so translation of improved processes into commercial deployment will likely occur reasonably rapidly thereafter.

Competing processes include gasification of biomass to syngas and production of liquid fuels from that via the Fischer-Tropsch process. This route is preferred by many manufacturers of vehicles, since this fuel can be synthesised to match the specification of current fuels (for which vehicles have been optimised) better than other biofuels. However, there are more energy losses in this process, so the efficiency is somewhat lower. To date the Fischer-Tropsh process has only been proven 'economic' at large scale with abundant nearby feedstock (e.g, coal for Sasol, South Africa and gas in Qatar).

Are there any risks? As we have already mentioned, there needs to be more work on the energy balance and GHG savings from different techniques, and costs associated with pre-treatment need to be reduced (these issues are being addressed in BSBEC research). Another issue that is emerging in the blogosphere[8] is the problem of potential competition for agricultural wastes, for example, the use of wastes in the construction and furniture industries which use composite panels. Again, this is a matter for public policy.

Question 9. Is the use of the following technologies to develop new approaches to biofuel production appropriate? Why?

From our perspective as BSBEC scientists working in the crop, plant, microbial, cell wall, fermentation and biochemical sciences, all three (advanced plant breeding strategies, genetic engineering and synthetic biology) are necessary and appropriate as are advances in 'bioengineering' for pre-treatment of biomass. The challenge is so enormous that we cannot afford not to make use of these approaches. In general, genetic engineering applications should be examined on a case-by-case basis and all potential approaches, including but not exclusively GM, should be considered. It would be unethical not to use GM in the laboratory to study processes of plant growth and biomass deconstruction as this technique enables more rapid and cost effective progress than alternative methods (where those exist). For some crops, it will be possible to improve lignocellulose properties for biofuel production using advanced breeding strategies but this will not always be feasible depending on the genetics of specific crops. There is a strong case, therefore, for the use of GM biofuel crops where the sustainability analysis suggests it is appropriate. GM crops are already widely grown and accepted in many parts of the world so it is certain that other countries will be deploying biofuel applications involving genetic engineering. UK research in this area will not be competitive if we refuse to use all of the best available technologies. While we believe that any risks are likely to be small compared to the known risks of using fossil fuels, we recognise the high level of public concern around this subject. There is therefore a need for greater engagement between different parties to aid mutual understanding around different approaches to risk assessment and to inform decision-making.

Question 10. What are the most important intellectual property and access issues raised in new approaches to biofuels? What is the best way of governing these?

IP tends to create a fragmentation of research efforts, with each academic group co-sponsored by different industrial partners, hence creating restrictions on their capacity to communicate freely with each other. Patents in biotechnology might limit the spread of technologies, but this is similar in other biotech fields. Without changes in the law this situation will remain.

Question 11. What are currently the main constraints to R&D in new approaches to biofuels?

There is insufficient funding and research capacity in this area. In the UK in particular, the lack of a significant plant biotechnology industry retards progress and investment in crop/feedstock optimisation. Cohesion between researchers is also an issue, often due to the IP issues mentioned above that are related to having industrial co-sponsors.

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[8] http://mjperry.blogspot.com/2010/01/law-of-unintended-consequences-biomass.html

There is insufficient long-term security as policies and incentives have not yet been stabilised to be sure of a market. Given that this is still a young field, there are a number of different alternative technologies making it unclear which approach is viable and will be adopted.

Question 12. Where should R&D for new approaches to biofuels be targeted, and who should decide about future biofuel R&D strategies?

This needs to be reviewed constantly, since it is not clear yet which of the new avenues are going to bring most benefits. The criteria for assessment should be sustainability, GHG savings based on sound LCA, and transferability (can particular techniques be used anywhere on the globe, or only in niches?)

Decisions should be science and evidence-based, will need to involve stakeholder engagement, but will ultimately need to be taken by government (on UK and EU levels).

It is important that government should fund both fundamental science and its commercial implementation – and provide a policy background that encourages industry to participate in the latter.

Funding should be targeted to approaches likely to have substantive contribution to world or UK energy use, not small niche approaches that could never be sufficiently scaled to have an impact on overall GHG emissions or energy use.

Funding additionally needs to be directed at understanding market, institutional and societal aspects towards biofuels. For example, a fully functioning biofuel industry will be dependent on sufficient feedstock – understanding the barriers and incentives to the supply of such feedstock, and the longer term assurances over such supply will be as essential as developing the technology to enable efficient biofuel production. While this has been previously examined by the Biomass TaskForce led by Sir Ben Gill, some level of ongoing monitoring can be helpful for understanding the dynamics of this issue.

Question 13. Are new approaches to biofuels likely to raise problems related to land use? If yes, how? If not, how do new approaches avoid these issues?

This is a very tricky and important question; the answer depends on the feedstock and the farming practices in the region in question. Lignocellulosic and algal biofuels should have considerably smaller impact than ‘1st generation’ biofuels, with intelligent management. If straw or forest residues are used, then the effect is likely to be small. If dedicated energy crops are grown, these will have to be on sites unsuitable for efficient food production.

From an economic perspective, we might draw the following inferences. Assume a new technology (e.g. plant genetics) increases the amount of biomass per hectare that is technologically achievable. Further assume that farmers are efficient and operating at this technological level and that the food yield of this biomass remains constant: i.e. food yield is unaffected by the technological change. Under these circumstances, it may be possible to meet increased demand for biofuels without reducing the area of land in food production.

Alternatively, assume a new technology that makes better use of existing plant genetics: e.g. fermentation of cereal straw. Effectively, this creates a new market (or increases a very limited market – straw is currently used for heating purposes in the UK) and thus a new source of demand for straw. In a country like the UK, there would be land use implications – less straw would be available for animal feed and bedding and less straw would be incorporated into the ground after harvest. Depending on the price of straw (which will increase because of the new market), there may be land use implications – for example, substitution of grassland for cereal crops. However, it is worth noting that land use in Developed Countries is already substantially distorted by the effects of agricultural policies.

Question 14. What differences are there between the developed world and developing countries with regards to the potentially problematic effects of future generation biofuel production on land use?

In many developing countries, subsistence farming is still a prominent part of land use. Subsistence farmers need to be treated equitably and the impact of wider problems around land ownership patterns on biofuel production needs to be considered. In countries with especially rich resources in natural biomass, substitution with farmed biomass could be counterproductive. In general, these issues should be assessed on a case-by-case basis so that local complexities and community views are understood.

Question 15. Should iLUC be considered when evaluating the GHG emissions savings of new approaches to biofuels, and if so, how?

Most definitely; the 'how' is very difficult to answer – certainly the same yard stick would need to be used in all cases, hence there would need to be global agreement on which method is being used. The problem is that there is no good way of modelling this at present. There is elasticity in land use efficiency/productivity that is difficult to factor in, and so land use change is not easy to calculate. iLUC calculations should be avoided until this is resolved satisfactorily. iLUC calculations, if used, should be applied to all uses of land. Rather than subsuming the impact of iLUC within a life cycle analysis (LCA) calculation, it may be best to consider the issue separately and explore potential scenarios of different land-use options.

Question 16. What advantages and disadvantages for environmental security could new approaches to biofuels have? How could harms for environmental security be dealt with?

They are likely to have a less detrimental impact on the environment, since these issues are taken into consideration in the development of advanced biofuels. The water footprint of biomass energy has been widely highlighted as an issue and the levels of water use by bioenergy crops needs to be monitored further. Richter et al (2008) present findings to suggest that bioenergy plantations in the UK, specifically of Miscanthus, are water-limited in some areas. Although Miscanthus makes efficient use of water, yields are affected by low soil available water capacity. Sustainability of plantations depends on ensuring adequate water supply from the soil. Decisions on siting of plantations must therefore make best use of soil and geological data. Use of water at other stages of biofuel production should also be considered. BSBEC research includes work in the Lignocellulosic Conversion to Bioethanol (LACE) project on techniques to reduce the amount of water required for pre-treatment of biomass feedstocks and in conversion to biofuels

The impact of perennial bioenergy crops on biodiversity is an emerging area of research. A study in the RELU-Biomass project found that biodiversity, as measured by abundance of butterflies, was greater in the margins of SRC willow and Miscanthus crops than around arable crops (Haughton et al 2009). The choice of butterflies as the most suitable indicator of biodiversity emerged from discussions with stakeholders, highlighting the value of deliberative engagement methods in this area as well as in the debate over biofuels in general. The paper cites earlier research on biodiversity impacts of SRC willow in particular which also found a positive effect when looking at densities of invertebrates and wild plant species.

The removal of agricultural residues has been noted as an activity that must be properly understood in specific projects so that negative impacts on soil fertility and conditioning are minimised; however, guidance does exist for ways of managing this issue (AEA Technology for DEFRA 2008).

In general, biodiversity will tend to be reduced if natural biomass is replaced with farmed biomass. Biodiversity may be increased if farmed biomass replaces conventional commercial crops. Biodiversity and environmental services generally are under-valued – in economic parlance, they are public goods for which there is either no incentive to produce (e.g. biodiversity) or no incentive not to pollute (e.g. sediments).

In conclusion, biofuels may be worse or better than conventional agriculture, but without either market mechanisms (e.g. incentives and taxes respectively) or command and control policies (e.g. planning regulations) environmental security will decline.

Question 17. Are new approaches to biofuels likely to raise problems related to food security? If yes, how? If not, how do new approaches avoid these issues?

This is obviously a key issue as we have already observed and requires further assessment. In general, we can say that second generation techniques are likely to have less impact than first generation biofuels. Second generation feedstocks use plants such as energy grasses and trees which are not grown for food, and non-food parts of food crops e.g., straw. This partly overcomes the issue of using food as fuel, but there are still considerations regarding the use of land to grow fuels rather than food.

According to a recent study arising from the RELU-Biomass and TSEC-Biosys projects, assuming that cultivation of Miscanthus is restricted to ALC (Agricultural Land Classification) Grades 3 or 4 (these are not the highest yielding for these crops, but such a restriction would avoid stress on Grades 1 and 2 which refer to prime agricultural land), achieving the 350000 ha proposed by the UK government to meet renewable targets for electricity generation was estimated to displace 5.5% of arable cropping area for winter wheat and 5.9% for oilseed rape. The paper goes on to suggest that if current surpluses for winter wheat and oilseed rape are factored in, this displacement "would appear not to present a direct problem for domestic food production" (Lovett et al 2009, p.10). However, to meet current targets for renewable liquid fuels for transport, biomass production would need to increase beyond 350000 ha, putting some pressure on remaining land. Impacts of loss of surplus on global food security (or reductions in surplus) were not considered in the analysis. The authors also point out that under a different set of economic incentives, more pressure might be exerted on UK land for food production – for example, if the price of biomass feedstocks becomes competitive with grain prices, conversion of the highest-yielding arable land (ALC Grades 1 and 2) might happen. These points suggest a key role for public policy in managing the effects of biofuel production on food security.

Question 18. What differences are there between the developed world and developing countries with regards to the potentially problematic effects of future generation biofuel production on food security?

From a strictly economic perspective, food security is more important in developing countries as a greater proportion of (a lower) income is spent on food. However, food security is also a matter of improving incomes so that people can afford to pay for food (and thus encourage Developing Country farmers to produce).

Question 19. Are new approaches to biofuels likely to raise problems related to rights of farmers and workers? If yes, how? If not, how do new approaches avoid or benefit these issues?

From an economic perspective, working conditions or wages (incomes?) of farmers are social issues that are not necessarily linked to a particular technology, unless a situation similar to that described in Q20 arises. Health affects would depend on the relative use of crop protection products – will biofuel use more or less than the crop it replaces? If it replaces e.g. cotton, the answer is probably 'less'.

We are aware of problems over the land rights of farmers and large scale developments for the production of biomass crops for biofuels in some developing countries. This is an issue that needs to be better understood.

Question 20. What differences are there between the developed world and developing countries with regard to the effects of the production of future generation biofuels on the rights of farmers and workers?

It is perhaps worth noting as a parallel the factors that made for economic success with the 'Green Revolution'. New varieties, particularly of rice, were adopted relatively rapidly because there was a benefit to farmers from adopting – more food and greater revenue. The technology in itself did not affect different types of farmers in different ways, as the inputs needed – more fertilisers and pesticides – were divisible; you could buy one kg of fertiliser or 100kg at the same price per kg. However, markets were biased towards larger farms – larger farmers had greater access to credit than smaller farmers. Hence, adoption was earliest and fastest on larger farms. Late adopters lose out, particularly if output prices fall as production increases. Thus, the rights of farmers in Developing Countries are more likely to be affected by market structures and government policies than by the technology itself.

However, if larger scale, 'lumpy' capital investments are needed (e.g. tractors) the technology will itself tend to be biased towards larger farms. Second, some people still question the green revolution in terms of its environmental impacts which in turn, affect the welfare of farmers. To try and anticipate these potentially wider impacts, ongoing technology assessment is essential.

Question 21. Where do you think investment in new approaches to biofuels should be directed and where should it come from (public sector, private sector or public-private partnerships)?

Research comes in many forms from blue-skies fundamental research through to product development and testing. It is important that there is a balance across this spectrum and that new research is focused on topics that are of real concern; the use of gap analyses can be of value.

At present there are several areas of biofuels research in the UK that are not fully addressed. We need to develop a capability to pull good ideas through the research pipeline.

As indicated in our response to Question 12, funding should come from different sources at the various stages of the research pipeline. There can be no hard and fast rule. However unless there is a clear commercial driver it is likely that government will have to fund the fundamental research, gradually handing on to industry as commercial value is established.

In the case of BSBEC the BBSRC has made a significant investment in bioenergy research. This public sector investment has been accompanied by private sector funding by the industry partners indicated in Table 1.

Question 22. Which policy issues in relation to new approaches to biofuels would you like to bring to our attention?

The development of a 2nd+ generation biofuels industry requires investment of time and money that will take some time to amortise. If it is to be achieved it is vital that research institutions and industry receive clear long term policy signals that provide confidence for this investment. Thus 2nd generation biofuels are unlikely to be widely adopted in the UK without specific incentives that are stable that would encourage farmers to provide reliable supplies and ensure industrial investment has a secure return.

Policy decisions also need to attend to the issues mentioned previously in response to other questions, i.e., ensuring minimal conflicts with food production by making the right choices on land that is to be used for perennial bioenergy crops, resolving competition for different uses of agricultural wastes, and providing support for further work on key outstanding questions including iLUC calculations of GHG savings.

Question 23. What would be the most effective policies a.) to promote and incentivise; and b.) to regulate the development of new approaches to biofuels?

For relevant policies to be established it is necessary to agree a hierarchy of use for biomass. It is our view that at least in the medium term biofuels are the only realistic substitute for petroleum based fuels. They should therefore be placed at towards the top end of the hierarchy of use and incentives provided in preference to CHP or electricity generation. Even though these latter uses may provide a more energy efficient use of biomass, their end application can be achieved by a number of alternative means.

Question 24. Are there any other issues not mentioned in this consultation that we should consider in the ethical evaluation of new approaches to biofuels? Please expand below.

None.