New approaches to biofuels

A response from the Society of Biology to the Nuffield Council on Bioethics

March 2010

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In recent years, moves towards increased use of biofuels have raised a number of concerns. These relate primarily to first generation fuels, employing large scale production of biomass, and to the inefficiencies in their conversion to energy. To bring about improvements, we recommend that:

1. Material that can be used as food for people or livestock should not be used as feedstock for biofuels because to do so would adversely affect food security.

2. Non-food crops, waste biomass, algae, and microbes could be used to produce next generation biofuels, but only if comprehensive lifecycle and ecosystem analyses show that sustainable production is possible. For example, intensive monocultures of non-native species (e.g. *Miscanthus sp.*) may have negative impacts on water quality, biodiversity and landscapes.

3. Land with high biodiversity value should not be used to grow biofuels, nor should their growth ever displace other uses onto such land unless there is clear justification and no viable alternative. Land-use choices should be subject to comparative analysis through an ecosystem approach.

4. Biologists can play a key role in generating new approaches and technologies towards the goal of sustainable biofuel development.

5. It is imperative that adopted biofuels are subjected to full life-cycle analysis for energy efficiency, ecosystem and social impact, and sustainability. Sustainability criteria should be mandated EU-wide. The recent decision in favour of optional recommendations rather than binding criteria is disappointing and very unlikely to succeed in delivering the degree of environmental stewardship so urgently needed.

6. A robust policy to reduce energy use should be a primary objective. The promise of biological and other energy sources should not deter these efforts. Energy saving measures are often more environmentally sustainable, and significantly cheaper than novel fuels and processes. Energy saving and efficiency measures should be implemented vigorously by governments, organisations and individuals.

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Question 1 What is your view on society moving towards greater use of biofuels?

The trend towards greater proportional use of renewable sources of energy, including biofuels, is now well established and likely to increase. Biofuels have the potential to contribute to amelioration of some current problems of energy production and use. However, their overall contribution depends heavily on how the relevant technical, ethical and practical issues are addressed and a careful approach is required to develop policies that effectively drive, and monitor, sustainability.

The capacity of biofuels to completely replace fossil fuels is unrealistic in the absence of a revolutionary scientific advance. Increased use of sustainable and energy efficient biofuels should be encouraged alongside other alternative energy sources (solar, wind etc.). The appropriate mix will vary from place to place depending on the social and political as well as the biophysical environment, and a diversity of small-scale solutions could prevent dependency on any one source.

Increased use of biofuels should not become a dominant strategy for climate change mitigation promoted at the expense of investment in other strategies such as efficiency measures, alternative energy (e.g. wind, solar, wave and tidal) technologies and ecological restoration, which may be more cost effective. An emphasis on the development of biofuels should not detract from the need for individuals and society to change behaviour towards less energy intensive patterns of consumption. The Gallagher Review of July 2008 found that in terms of their evidence on greenhouse gas (GHG) savings "the potential risks of biofuels outweigh their benefits"[1]. This review recommended reducing the rate of change to biofuel use until adequate controls on management of land-use change could be implemented and enforced effectively. The report also recommended that feedstock be produced on idle or marginal land and that the use of crop wastes and residues be encouraged with incentives. However, these recommendations alone do not assure sustainability as some marginal land can have high biodiversity value and the use of wastes and residues as feedstocks can compete with other uses in combined heat and power generation or soil improvement.

Question 2 What are the most important ethical challenges raised by the prospect of future generation biofuels?

The challenge lies in how to develop sustainable production and use methods that produce significant energy gains (over the whole production cycle), contribute to a net reduction in greenhouse gas emissions and which do not adversely affect ecosystems (including their human inhabitants). A key challenge is and will be to take account of potentially adverse impacts on people, especially the poor, in a system that is inevitably an economic one. Many areas used to grow feedstock for biofuel (e.g. palm oil) are in the tropics. This exploits advantageous growing and sunlight conditions but thereby exposes some of the world's poorest communities to harm from loss of agricultural land and environmental degradation.

First generation biofuels in particular have impacted food security through competition for land and water. Food price increases or reduced availability will inevitably hit the poorest people the

[1] The Gallagher Review of the Indirect Effects of Biofuels Production, Renewable Fuels Agency, 2008. http://www.renewablefuelsagency.gov.uk/iluc

hardest. Similarly, any increase in fuel price will also disadvantage the poor. Biofuels are currently, significantly more expensive to produce than fossil fuels, thus it is important that fiscal incentives and tax regimes for of the various technologies are carefully formulated and applied. There is a real danger of causing more environmental harm than good if biofuel production and use is not intelligently planned.

There is the risk that patent laws and overly stringent regulatory framework for such new technologies could restrict small companies from contributing to this sector. Given the certainty of fundamental changes to energy infrastructure, there is a positive ethical imperative to research and develop diverse biofuels, as part of the solution to society's fuel needs.

Increased use of land for biofuel production, including marginal or 'idle' land will require the use of water. In 2009 Prof. John Beddington, HM Government's Chief Scientific Adviser, warned that increasing population and food demand will cause human global water demand to increase by 30% between now and 2030. The fresh water available per head of population is declining and one in three people on earth are already facing water shortages[2]. Climate change is predicted to drive significant changes in the distribution and availability of water, coupled with increasing demand, this will pose a real challenge. Investment in agricultural research and development should be increased. Breeding of drought and saline resistant food crops could contribute to the solution of this problem along with similar efforts in relation to biofuel crops. Similarly attention should be paid to the source of water used for cultivation of biofuel crops, including consideration of wastewater sources.[3]

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

The Society of Biology calls upon the expertise of its individual members and of its member organisations, listed below. Some member organisations (MOs), for example the Association of Applied Biologists (AAB) are actively involved in this area, holding conferences and publishing proceedings.[4] This response has benefited especially from contributions from the AAB, the Society of Experimental Biology (SEB),[5] the British Ecological Society (BES) and from working groups convened for previous inquiries on biofuels.[6]

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?

Change will be influenced by market forces including the relative costs of fossil and biofuels. At present there is inadequate valuation of the environmental costs of production of both fossil and biofuels which represent negative externalities. The local balance between food and energy

[2] Reported at http://news.bbc.co.uk/1/hi/8213884.stm Accessed 16 March 2010
[3] Clarens et al (2010) Environmental Life Cycle Comparison of Algae to Other Bioenergy Feedstocks *Environ. Sci. Technol. 44* (5), pp 1813–1819. Available at http://pubs.acs.org/doi/abs/10.1021/es902838n
[4] Aspects of Applied Biology (2005) 146.
[5] Society for Experimental Biology Plant Section and GARnet (Genomics Arabidopsis Resource Network).
[6] Are biofuels sustainable? A response from the Biosciences Federation to the Environmental Audit Committee's inquiry (2007)

security may affect biofuel development as will limitations of inputs such as water and nitrogen. Government and international policies employing targets, subsidies and incentives will be very significant and are likely to reflect multiple concerns including greenhouse gas (GHG) emission reduction, industrial sector support and integrated transport policies. The basis of any perceived GHG emission advantage offered by biofuels relative to fossil fuels is likely to come under close scrutiny in the light of past misconceptions. Future policies that target research into increasing the efficiency of biofuels are likely to yield benefits in terms of cost reduction. Biofuels produced from household and industrial wastes that would otherwise end in landfill would be doubly beneficial. The development of strong policies to ensure that land-use change is well managed and monitored will be very important, including consideration of schemes such as Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanisms. Additionally, the level of investment in agricultural research and development will be a major factor driving future development of biofuel crops.

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?

The most effective approaches may well vary with circumstances. It is important that all technologies are explored and pilot studies carried out to define and value the actual advantages and disadvantages, using full life cycle analysis, including indirect land use change, and consideration of ecosystem, economic and societal implications.

Technological advances, including plant breeding have the potential to enhance emission savings while factors such as distribution of fuels can reduce their benefit considerably. Similarly, the undesirable aspects of bioethanol production from wheat stocks could be balanced against the potential of the protein-rich livestock feed produced as a by-product to reduce the demand for soya grown on deforested land. The Gallagher review recommends that life-cycle analyses to assess GHG emissions take into account not only indirect land use change but also the avoided indirect emissions from the use of co-products.[7] At present, accurate carbon accounting is a significant challenge in the development of effective remedies to climate change, given the vast number of factors involved and the complexity of their interactions. The two main biofuels currently used in road vehicles, bioethanol and biodiesel, differ in their GHG emissions, with biodiesel generating significant amounts of nitrous oxide. GHG emissions should not be the only criterion in selecting the best biofuels.

Algal and marine biomass offer potential for biofuel yield from areas not normally used for food production. Nevertheless, recent life-cycle analysis of algal biofuel production suggests that green-house gas savings on these fuels are in fact lower than previously thought, highlighting the need for comprehensive life-cycle analysis of all approaches before any are selectively encouraged.[8]

The 2010 review of the Renewable Transport Fuel Obligation (RTFO) shows that biofuel supplied to the UK accounted for 2.7% of the UK's total transport fuel. Only 9% of this came from UK

[7] The Gallagher Review of the Indirect Effects of Biofuels Production, Renewable Fuels Agency, 2008. http://www.renewablefuelsagency.gov.uk/iluc

[8] Clarens et al (2010) Environmental Life Cycle Comparison of Algae to Other Bioenergy Feedstocks *Environ. Sci. Technol. 44* (5), pp 1813–1819. Available at http://pubs.acs.org/doi/abs/10.1021/es902838n

feedstocks and of the remainder only 4% met sustainability standards.[9] More needs to be done to ensure that robust sustainability standards are applied and adhered to throughout the supply chain. Mandatory reporting, and penalties for failing to meet high standards could contribute very necessary improvements. Additionally, only 157m litres of biofuel came from wastes and by-products (representing 12% of total). This is the source of biofuels expected to deliver the greatest GHG savings. Greater use of wastes and residues should be encouraged with incentives.

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?

At national level, an energy strategy delivering sustainable self-sufficiency would be ideal. To have a diverse mix of energy sources utilising all available resources is key. This should be promoted through a broad spectrum of approaches, including funding research into alternative energies and support for businesses implementing these types of measures. We do not yet know enough to identify the long-term winning approaches. It remains essential to reduce energy consumption, for which there is considerable scope in the UK. This should not be sacrificed in the drive to promote biofuel 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?

This is constantly evolving and technological breakthroughs may completely change the economics of biofuel production and the subsequent economic multipliers. In the current market, primary producers usually obtain less benefit than those who add value to a product by its processing. The economic benefit also depends on the nature of the economy. Developments could easily have a detrimental impact in the country where the feedstock was produced if the economic benefit is repatriated to a commercial concern based in another country. Good regulation of biofuel production will be crucial to prevent potentially damaging consequences. However, any regulatory framework should not be so complex as to stifle small companies and restrict the profits to only those large enough to cope with an onerous regulatory system.

Question 8 Of all the new approaches to biofuel feedstock development, pretreatment 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?

Many techniques have a long history of use. Pasteur's demonstration of the production of butanol by fermentation in 1861 continued to be used commercially in South Africa until the 1960's. Evolving technologies include anaerobic digestion and the development of methods for producing biodiesel from algae (e.g. the Biomara project; http://www.biomara.org/); biodiesel from plant

[9] Year One of the RTFO, Renewable Fuels Agency, 2010. http://www.renewablefuelsagency.gov.uk/yearone

waste (based on engineered bacteria) and dedicated biomass crop production with crops bred and engineered for yield and processing qualities. Some technologies could be commercialised very quickly but there are always risks associated such developments. It will be important to conduct a rigorous risk appraisal before their general release. Significant developments are likely to come to fruition over the next 5-10 years, and probably even sooner.

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

- ***Advanced plant breeding strategies***
- ***Genetic engineering***
- ***Synthetic biology***

These are all important technologies both to produce feedstocks with high extraction rates and to provide enzymes for pre-treatment of wastes. The oil composition of oilseed rape, which is largely under single gene control, was changed dramatically over a period of 10 years using conventional breeding techniques. Modern genomic analysis has the capacity to accelerate this process both through GM and enhanced conventional breeding (for example using quantitative trait loci analysis (eQTL)). Additionally, the stigma attached to GM technology could be less of a problem in dedicated biofuel crop production than has been the case for food production in the EU.

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?

Most private industrial biofuel development will require IP protection to encourage investment. Biofuel crops are generally less developed than modern food crops. A restrictive IP environment which limits access to germplasm diversity will not be helpful. The costs of negotiating conflicting IP claims under UPOV[10], TRIPS[11], ITPGRFA[12] and bilateral FTA's is high. Inclusion of more biofuel crops in Annex 1 of the ITPGRFA would be helpful.

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

Some of the main constraints are: the difficulties in attracting funding for research that is perceived to be risky and speculative, especially between the commercial and academic sectors; limited public funding, and the availability of good model species (e.g. for marine algae).There is a need for greater development of whole organism biological research in the UK to facilitate production of agricultural and forestry biofuel solutions and to enable field assessment of their ecological impact.

[10] International Union for the Protection of New Varieties of Plants (UPOV): http://www.upov.int/index_en.html
[11] Trade-Related Aspects of Intellectual Property Rights (TRIPS): http://www.wto.org/english/tratop_e/trips_e/trips_e.htm
[12] International Treaty on Plant Genetic Resources (ITPGRFA): http://www.planttreaty.org/mls_en.htm

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

High level strategies to ensure that R&D funding is available to a wide range of candidate techniques are essential. R&D is already being carried out by commercial concerns. There is an interesting parallel with renewable energy generation where considerable funding went into onshore wind generation with rather less into tidal power, offshore wind and transmission networks. The latter are now seen to be key technologies for the future. This lesson is important in illustrating that broad seeding of candidate technologies is preferable to attempts to spot the winners. Effective consultation with all stakeholders is essential. Research into synthetic photosynthesis as well as biofuel generation from non-food crops and crop residue and marine biomass will be important as well as technical innovations to enable more efficient use in the transport sector (including aviation). In our recent submission to the RCUK Review of Energy 2010 we commented on the disparity in public funding of biofuel R&D between the US and the UK where this is deemed as predominantly a private sector activity.[13]

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?

Some new approaches may be less likely to generate problems than have first generation biofuels from agricultural crops. For example, the use of algae or waste products should have less impact on arable land use. However, the use of crop waste for biofuel production rather than ploughing-in inevitably removes nutrient elements and potentially impoverishes the soil. Maintenance of adequate nutrient cycling will be important. There are calls to utilise land currently not suitable for food crops, although in practice this is more difficult than it seems. For example, despite expectations that *Jatropha* could be grown on marginal soils, financially profitable yields are generally only achieved on more fertile land. Other land use issues such as impacts on biodiversity and the ecosystem services (including cultural services) provided by land will need to be considered if non-arable land is to be harnessed for biofuel production.

Life-cycle analysis of a biofuel must take account of indirect land-use change and avoided land-use for co-products. The scale of indirect land-use change is potentially larger for second generation biofuels than first generation crops, if grown on existing agricultural land. Second generation biofuels often use the whole plant in the production of feedstocks, thus removing the potential to make use of residues in, for example, animal feed. Crops usually grown specifically for use as animal feed are protein rich and so are grown on large tracts of land. Although second generation biofuels are likely to have co-products it is likely that these will be of most use in energy generation themselves and so are unlikely to have the avoided land-use benefits, in terms of co-products, currently offered by some first generation fuels.

The Gallagher Review argues that there is a need to shift biofuel production onto idle or marginal land, as a way of reducing the GHG emission, and food security concerns, associated with land-use change. The report suggests that this will require the development of an appropriate definition of idle land. Company reporting under the Government's 'Carbon and Sustainability Standard' of

[13] Society of Biology response to RCUK Review of Energy 2010 consultation: http://www.societyofbiology.org/documents/view/238

the RTFO did not record land-use change associated with the biofuel feedstocks they sourced. However, suppliers reporting fuel from agricultural feedstocks often recorded that they did not know the previous land-use for a proportion of their returns. When land use was known, this was reported as either 'by-product' or 'cropland'. Government reporting of savings in greenhouse gas emissions from the use of biofuels in the UK was given as 46% compared to the equivalent use of fossil fuels in 2008/09. This is undermined by lack of consideration of indirect land use change. Methodologies for accounting indirect land use change are poorly developed and should be refined in order that calculations of life cycle GHG savings through biofuel use are robust.

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?

The ecological quality of the land used, and the value of its ecosystem services, might be higher in some developing countries, and the degree of legal protection of such valuable land likely to be weaker or not enforced. Land in developing countries may be more prone to problems caused by poorly managed biofuel crop planting due to lower regulatory standards. Currently significant areas of land in developing countries are in use to produce food and other crops for the developed world. Conversion of use to biofuel production might need to be considered in this context but local food security and wellbeing should be a primary concern. Knowledge exchange and capacity building will be vital to ensure that developing countries have access to scientific, technological and sustainability information regarding developments in biofuels.

Question 15 Should indirect Land Use Change (iLUC) be considered when evaluating the GHG emissions savings of new approaches to biofuels, and if so, how?

Unless a complete analysis is carried out, the results may be misleading. Analysis of iLUC is a relatively recent measure and the field is developing. Clear, comprehensive and agreed land use definitions will be required and these should be underpinned by good ecosystem service valuation. A major problem at this stage is that the use of different methodologies can cause significant market distortions. Brazil, Argentina, Indonesia and Mozambique (all of which are biofuel-producing nations) are concerned that possible EU actions could impact their export trade. Many organisations believe that it is only by taking robust account of iLUC that globally fair and equitable systems can evolve. The Commission of the European Communities is currently preparing a report on the effect on iLUC of biofuel production and whether it should be accounted. The report is expected to be completed by mid 2010.

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

Some methodologies offer scope for reducing pollution and GHG emissions thereby reducing the likelihood of dangerous climate change. These benefits also include reductions in material sent to landfill, or utilising CO_2 produced by industry. Environmental insecurities are likely to come from poor implementation, such as growing biofuel crops in intensive monocultures; failing to mitigate

for utilisation of feedstock materials such as wood or crop waste that would otherwise contribute to ecosystem functioning as habitat or soil improver, and impact on water table and cycling. Thus, as with any industry, risks of adverse environmental security should be handled by properly audited risk appraisals, consent procedures and enforcement.

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?

Problems will inevitably be raised if the growing of biofuel crops is at the expense of crops that would otherwise feed people. There may be cases where the production of biofuel crops provides an adequate income to purchase food from areas better suited to food growing. However, this compromises local food security in favour of trade-dependant security. Diversion of people and skills from food to biofuel production could also be relevant.

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?

Lack of food security negatively impacts the poor in all countries and prioritisation of measures to reduce this should be a policy priority in all areas.

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?

This will be variable and depend on which new approach is being considered. It will also depend on the scale and ownership of the production facilities. New approaches need not be as centralised as fossil fuel production. This could benefit small producers if the regulatory system is not too restrictive or onerous and if there is adequate infrastructure and access to markets.

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?

Developing countries could benefit from developing their own capability to produce biofuel, rather than selling land or low value raw materials to more developed countries. Farming systems research will be needed to refine efficient systems to maximise and harmonise local biomass and food production. This could be aided by mechanisms such as the CGIAR International Institutes. [14]

[14] Consultative Group on International Agricultural Research (CIGAR): http://www.cgiar.org/

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)?

Support should come from all sectors. The public sector and the Research Councils should support basic research and promising approaches and technologies that are perceived to be at too early a stage of development, or too risky, for the private sector.[15] However, private sector involvement is key as successful technologies will inevitably accrue significant economic reward. Publicly funded research now also carries the benefit to developing countries of being largely open-access allowing easy access to published results; many journals also make material available to developing nations at a reduced rate or for free under voluntary schemes such as AGORA.

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

There is a need to develop standardised, agreed and scientifically valid protocols for assessing biofuel technologies and their implementation. It is the responsibility of governments, with the best scientific and other advice, to understand the positive and negative impacts and ensure that their policies do not create new problems. In this context, we are disappointed to note that the European Commission recently ruled out imposing binding EU-wide sustainability criteria for biomass, offering member states recommendations for national action instead[16]. We think that this is an abrogation of responsibility, especially since demanding targets for biofuel use introduced by the Commission are believed to have led to undesired effects on the environment and food security. The review of the RTFO suggests that voluntary schemes to incentivise environmental and social sustainability need to be strengthened. Only 20% of the feedstock supplied met the Government's Qualifying Environmental Standard (that biofuel cultivation should not cause loss of carbon stocks or biodiversity or damage air, soil or water quality). This is lower than the Government's target of 30% of all feedstocks for the 2008/09 year. The review of the RTFO concluded that "significant improvement will be required by all suppliers to meet the challenges of mandatory sustainability requirements under the EU's forthcoming Renewable Energy Directive." In the absence of binding criteria it is unlikely that suppliers will indeed make the necessary efforts to improve their performance.[17]

Subsidising biofuels to provide them at a competitive price in the initial stages (further taxation of fossil fuels would be unpopular and might disadvantage the poor) will be necessary due to currently low efficiencies and expensive technology. However, it is important that this is balanced with keeping the arena open for new innovation and more efficient technologies (i.e. avoiding stifling new techniques because older, less efficient technologies are cheaper due to subsidies) – this will be challenging but is very necessary.

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[15] Society of Biology response to RCUK Review of Energy 2010: http://www.societyofbiology.org/documents/view/238

[16] http://www.euractiv.com/en/energy/eu-rules-out-binding-criteria-biomass-news-290021

[17] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/192&format=HTML&aged=0&language=EN&guiLanguage=en

The potential contribution of basic biology in terms of insight into and harnessing of photosynthetic processes should not be overlooked nor should the potential contribution of microbiological research.

In its report *Reaping the Benefits,* the Royal Society highlighted under-investment in agricultural research and development as an area which must be addressed to tackle global food crop insecurity.[18] The Society calls on Research Councils UK to develop a cross-Council 'grand challenge', with funding of £2 billion over ten years and £50 - £100 million of new Government money in addition to existing research spending. Such investment in agricultural research and development would equally benefit the development of new biofuel crop varieties, for example those which could be successfully cultivated on marginal and degraded land and thereby support food security efforts.

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?

Policies alone are not enough. There needs to be effective action associated with them based on understanding the real challenges. EU leaders have already established sustainability criteria for biofuels in the Renewable Energy Directive: biofuels must offer at least 35% carbon emission savings compared to fossil fuels with the figure rising to 50% in 2017 and 60% in 2018. However, this does not take account of iLUC. The relative negative or positive impact of biofuels on GHG emissions seems to vary considerably depending on the crop and zone of production although where impact studies use different protocols the robustness of conclusions is compromised. Biofuels are no different to any other field of commercial endeavour. There are already controls on many activities to minimise environmental impact, and to a lesser extent adverse social impact. Procedures for rapid but effective evaluation of new technologies are essential to avoid stagnation due to over-application of the precautionary principle or of stifling innovation.

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?

Issues of cost should not be ignored, and life-cycle analysis for overall energy gain. Not all new generation biofuel technology has to be high-tech: subsistence and semi-subsistence farmers can benefit from low-tech biofuel generation such as home-made biogas plants fuelled by waste products from their own holdings.

The Society of Biology is pleased for this response to be publicly available and will shortly place a version on www.societyofbiology.org . For any queries, please contact Dr Laura Bellingan, Society of Biology, 9 Red Lion Court, London, EC4A 3EF. Email: policy@societyofbiology.org

[18] Reaping the Benefits, The Royal Society, October 2009

Appendix

Member Organisations represented by the Society of Biology

Anatomical Society of Great Britain & Ireland
Association for Radiation Research
Association for the Study of Animal Behaviour
Association of Applied Biologists
Association of Clinical Microbiologists
Association of Veterinary Teacher & Research Work
AstraZeneca
Biochemical Society
British Andrology Society
British Association for Cancer Research
British Association for Lung Research
British Association for Psychopharmacology
British Bariatric Medical Society
British Biophysical Society
British Crop Production Council
British Ecological Society
British Lichen Society
British Microcirculation Society
British Mycological Society
British Neuroscience Association
British Pharmacological Society
British Phycological Society
British Society for Allergy Environment & Nutritional Medicine
British Society for Immunology
British Society for Matrix Biology
British Society for Medical Mycology
British Society for Neuroendocrinology
British Society for Plant Pathology
British Society for Proteome Research
British Society for Research on Ageing
British Society for Soil Science
British Society of Animal Science
British Toxicology Society
Experimental Psychology Society
Freshwater Biological Association
Genetics Society
Heads of University Biological Sciences
Heads of University Centres of Biomedical Science
Institute of Animal Technology
International Biometric Society
Laboratory Animal Science Association
Linnean Society
Marine Biological Association of UK
Nutrition Society
Physiological Society
Royal Entomological Society of London
Royal Microscopical Society
Royal Society of Chemistry
Scottish Association for Marine Science
Society for Applied Microbiology
Science and Plants in Schools
Society for Endocrinology
Society for Experimental Biology
Society for General Microbiology
Society for Reproduction and Fertility
Society for the Study of Human Biology
Society of Cosmetic Scientists
Society of Pharmaceutical Medicine
Syngenta
The Fisheries Society of the British Isles
The Galton Institute
UK Environmental Mutagen Society
University Bioscience Managers' Association
Zoological Society of London

Supporting Member Organisations
Association of Medical Research Charities
BBSRC
GlaxoSmithKline
Medical Research Council
Pfizer UK
Wellcome Trust