This response was submitted to the consultation held by the Nuffield Council on Bioethics on *New approaches to biofuels* between December 2009 and March 2010. The views expressed are solely those of the respondent(s) and not those of the Council.

University of Cambridge Bioenergy Initiative

QUESTIONS ANSWERED:

Question 1

ANSWER:
Unless our behavioural patterns and business practices were to change drastically to eliminate the need for non-fossil liquid fuels, greater use of biofuels in the future is unavoidable, for several reasons: - supplies of fossil fuels are limited (even coal, converted to liquid fuel via Fischer Tropsch, will eventually run out) - even if they were unlimited, their exclusive use without CCS (which is not achievable for fuel used in transportation) would exacerbate climate change - of the spectrum of renewable energies, only biomass can currently lead to liquid transport fuels, on which aviation, sea travel and HGV depend and are likely to stay dependent. It is therefore essential that sustainable biofuels are developed which provide actual GHG savings, in parallel with reducing demand. Both lignocellulosic and algal biomass could make a substantial contribution internationally as part of a mix of alternative transport fuels.

Question 2

ANSWER:
1) Limited availability of land and water necessary for the production of biomass 2) Pressure on the use of biomass for various applications: food, feed, platform chemicals and energy generation 3) LUC and iLUC driven by demand for Bioenergy, especially in areas of the globe with less regulation, (leading to deforestation of rain forests etc). 4) The exploitation of 'local' plant varieties or algal strains by multinational organizations - eg who 'owns' a good variety/strain used for large-scale cultivation in a particular location?

Question 3

ANSWER:
Yes; all members of the University of Cambridge Bioenergy Initiative (http://www.bioenergy.cam.ac.uk/) conduct research on the subject, read scientific publications, attend conferences, and engage in discourse with academia, industry, governmental organisations, funding bodies and NGOs on biofuels.

Question 4

ANSWER:
Drivers for the development of future generation biofuels: Price (stable, and competitive with fossil fuels), availability of feedstock, fear, policy intervention; of those given in the pre-amble to the question: the need to mitigate climate change and achieve lower greenhouse gas (GHG) emissions; worries about energy security. Policy priorities: sustainability across the whole supply chain, Life Cycle Assessment of GHG and energy, security of feedstock supply, stability in incentives and regulation, setting of realistic values on the cost of carbon emission (i.e. higher - given land areas required, even with algae, renewable energy sources only make sense as part of a larger policy in which society reduces its carbon dependence); development of an integrated strategy for training and research in key areas. Advantages: Income for farmers, coupling production of biofuel with generation of high value co-products to make best use of biomass and to provide financial incentives (biorefinery concept) – eg algal biomass could deliver sugars/oils for fuel, and protein for feed; lignin in lignocellullosic biomass could be basis for platform chemicals, cellulose feedstock for biofuel. However, note that the quantity of biofuels required may flood the market for co-products, thereby reducing their value – co-products should ideally also be required in large quantities.

Question 5

ANSWER:
It is unlikely that a single solution will answer all needs, so all approaches need to be considered. Different solutions are likely to be needed in different locations, and multiple approaches in one location, e.g. combining algal growth with anaerobic digestion. At present, the best estimate is that biofuels using abundant residues or low input energy crops will lead to the greatest GHG savings, such as use of sugarcane bagasse after sugar production in Brazil. Note that any estimates of GHG savings need to be rigorous and critical; otherwise they are counter-productive. In the example given in the pre-amble to the question, how would the quoted GHG savings change if land-use changes were taken into account?

Question 6

ANSWER:
Further research is needed before this can be answered definitively. However, some indications can be made on the basis of current knowledge. Energy security will arise by providing 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 transport use, and such straw is therefore an attractive target for development for UK energy security. Anaerobic digestion and biogas generation also represent a promising approach (albeit not for aviation needs). The gas can be fed into the grid, can be burned to produce electricity and heat, and can be 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. The technology for algal-based biofuels is at a much earlier stage, but it should be noted that, contrary widespread views, the limiting factor for algal growth in e.g. the UK is likely to be temperature rather than light. This can be addressed using waste heat. We do not exclude any of these approaches at this stage, and stress that all decisions should be based on sound evidence.

Question 7

ANSWER:
Again, it is too early to answer this definitively. It is not yet clear that any one approach is intrinsically better in this respect, or that any approaches should be excluded. We note that most of the R&D investment so far has been private (e.g. oil companies) rather than public money. It will therefore be important to balance the (legitimate) interests of those companies in exploitation (to get a return on their investments) with other needs, especially those of developing countries. As for Qu 6, we stress that all decisions should be based on sound evidence.

Question 8

ANSWER:
We note that the pre-amble to this question refers to “marine resources, such as algae”. We take this to refer to “aquatic resources, such as algae” as it is not clear that marine algae are to be preferred over freshwater ones. It is difficult to answer this question at present. There are very many early but competing technologies for biochemical conversion routes using plant material. Some are likely to be commercialised in the next year or so, and be economic by about 2013/2014. Algal biofuels (for which the same question applies) are likely to take longer. However, there are other issues besides the economics of production. For example, gasification of biomass to syngas and production of liquid fuels from that via Fischer-Tropsch is preferred by many manufacturers of vehicles, since this fuel can be synthesised to match the specifications 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.

Question 9

ANSWER:
All three approaches are likely to be necessary. Given the enormity of the challenge, we cannot afford to

exclude any of them a priori. Appropriate risk assessment and management strategies would be needed, but the risks are likely to be small compared to the known risks of using fossil fuels at current rates. We note that the question does not distinguish between the use of the technologies in the lab, and in the field. For example, in our view it would be unethical not to use genetic modification techniques in the laboratory to study processes of plant growth and biomass deconstruction. There is a strong case also for the use of genetically modified biofuel crops where the sustainability analysis suggests it is appropriate. It is difficult to consider the methods quoted in isolation; for example, synthetic biology relies on the methods used in genetic modification. Also, it is essential to ask questions such as this in a way that avoids provoking a given response. For example, although the pre-amble refers to “genetic modification”, the question itself asks about “genetic engineering”. The latter is a more emotionally charged term, and more likely to elicit a negative response than the former.

Question 10

ANSWER:
The issues raised are not, in principle, different from those in other areas of biotechnology. Some of the problems may be more pronounced, given the fragmentation of research efforts, with different groups sponsored by different industrial partners, making communication among the groups more difficult. There are also issues of ownership of naturally occurring strains (e.g. of algae) adapted to grow in particular areas. These issues are similar to those concerning plants etc with medicinal properties.

Question 11

ANSWER:
There are (i) a lack of resources and (ii) a concentration on short-term benefits. (i) There is a lack of funding, especially from government in some areas, such as algal bioenergy work. Although there have been many discussion meetings about algal bioenergy, they do not yet appear to have resulted in significant government funding becoming available. There is also the risk of a shortage of trained manpower to fill R&D posts. This is due in part to a decline in funding of basic plant science over the last few years and in part to the low esteem of plant sciences in schools as compared to medical research. Funding has also been complicated by a lack of cohesion among researchers, often due to IP issues related to having industrial co-sponsors. (ii) The fact that bioenergy research is a young field, with many alternative technologies means that it is unclear what the most beneficial approaches should be. Partly as a result of this, there has been a tendency to concentrate on short-term results, such as the greater energy recovery from biomass by burning for CHP (combined heat and power) or even electricity alone. Burning for electricity can also be more economic. There needs to be an economic or regulatory incentive to use the biomass for biofuel. For example in Brazil, more profit could be made by burning bagasse for electricity than by conversion to ethanol. There needs therefore to be a premium on liquid fuel uses of biomass.

Question 12

ANSWER:
(a) This is likely to need to be reviewed constantly, since it is not clear yet which of the new avenues are going to bring most benefits. Funding should be targeted to approaches likely to have substantive contribution to world or UK energy use. Criteria for assessment should include sustainability, GHG savings based on sound LCA, and transferability (can this be used anywhere on the globe, or only in niches?) Government funding should target basic enabling research at a fundamental level in science and engineering. A multidisciplinary approach will be essential, with input across scientific disciplines, industry, economics, NGOs etc. This may be difficult to achieve given the traditional approach of Research Councils to concentrate on particular areas with identifiable boundaries. (b) Decisions should involve stakeholder involvement, but would ultimately need to be taken by government (on UK and EU level).

Question 13

ANSWER:
With appropriate management, lignocellulosic and algal biofuels should have considerably smaller impact than '1st generation' biofuels. For lignocellulosic applications, land use will be significantly reduced if straw or forest residues can be used. For algal work, the land use will depend on whether the chosen route is photobioreactors, marginal land or off-shore cultivation. In the latter case, new legal questions may arise.

Question 14

ANSWER:
The differences do not fall neatly across the developing – developed divide. However, they are likely to include differences in (i) land area available (ii) other resources (water, nutrients etc) (iii) political/social infrastructure (iv) public approach to GM.

Question 15

ANSWER:
Most definitely. Reduction in GHG is a key driver in this, so iLUC needs to be taken into account. However, the problem is 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. Further research is required to develop models that include it. There will need to be global agreement on which method is being used, and calculations should be applied to all uses of land.

Question 16

ANSWER:
Lignocellulosic biofuels could have a positive impact on the environment, particularly in comparison to fossil fuel use and first generation biofuels, if suitable sustainability regulation is in place. First, use of crop residues such as straw and bagasse will have a benefit for the environment by reducing the need for fossil fuels. Second, perennial bioenergy crops can have greater biodiversity than arable crops, and use less fertiliser, herbicide and pesticides. However, water usage competition with food crops and natural environment are possible issues. For algae, there could be advantages as less land is required than for lignocellulosic fuels; also land that is unsuitable for crops can be used. Algal growth could be used as part of bioremediation of contaminated water, and there are obvious potential advantages over using fossil fuels. It still needs to be clarified if there are large enough areas of suitable land available to grow a substantial amount of fuel without environmental issues of land use change. There is a water requirement which may be an issue unless marine algae are used. There may be issues of disposal of 'spent' medium after harvest of algae, and issue of large-scale GM algal culture will need to be addressed. More systematic research is needed to identify, quantify and find solutions to potential harms.

Question 17

ANSWER:
Lignocellulosic fuels will have less impact than first generation biofuels. If they use residues from food production, or land that is not in efficient food production, their impact could be minor, but the use of land that is not productive for food needs to be managed. Algal fuels are likely to have similar potential problems to land plant biofuels, albeit less severe if algae are more productive per unit land area. If algae are grown offshore, there may be conflicts with fisheries.

Question 18

ANSWER:

As for Q14, the differences do not fall neatly across the developing – developed divide. However, they are likely to include differences in (i) land area available. For example, Brazil has large amounts of land available. (ii) other resources (water, nutrients etc) (iii) political/social infrastructure and regulation of sustainable farming practices. (iv) public approach to GM, which is more positive outside Europe.

Question 19

ANSWER:
There is a trend towards industrialisation of agriculture in both food and fuel production. Although this could lead to exploitation, it can also lead to better regulation of working practices and job security and working conditions.

Question 20

ANSWER:
We do not feel able to comment authoritatively on this.

Question 21

ANSWER:
It should be directed towards improved understanding of basic science & engineering underpinning algal and plant biofuels. A multidisciplinary approach is essential. Funding will need to be a combination of public, private and public-private. We need to be prepared to look very long-term.

Question 22

ANSWER:
We need a joined-up approach that provides funding and appropriate infrastructure for research and training. We need appropriate facilities to translate work from the bench to scale-up, a process analogous to translational medicine. Access to those facilities has to be simple for appropriate researchers – if people have to go through a long application process for money or access everything will be slowed down. The process has to be streamlined. At the commercial level, for widespread adoption in the UK we will need specific stable incentives to encourage farmers and aquaculturalists to provide reliable supplies and to ensure industrial investment has a secure return.

Question 23

ANSWER:
They are unlikely to be widely adopted in the UK without specific incentives that are stable, to encourage farmers to provide reliable supplies. Moreover, stability in incentives is important to ensure that industrial investment in expensive infrastructure has a secure return. The incentives could be taxation of GHG emissions, combined with a secure market and price for the fuel. Arguably, approaches that offer bigger GHG savings should be given bigger incentives. Increased public funding for research and training will also be important to ensure that the UK is well placed to influence the direction of development of the area, and to speed the transition to viable new technologies.

Question 24

ANSWER:
The most important message to communicate is that every single person can contribute to the solution – by reducing demand, and accelerating a cultural shift to acute energy awareness. All issues associated with biofuels become smaller and more manageable if demand is scaled down. The public must not be guided to think the problem is one for politicians, economists, scientist, industrialists and ethical councils to tackle and solve – ownership of the responsibility for the problem, as well as contribution to the

solution, must be shared much more wide-spread than it currently is. This is also one of the strongest antidotes to NIMBYism – which provides a major barrier for the uptake of sensible solutions.