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.

Novozymes

Question 1
What is your view on society moving towards greater use of biofuels?
Biofuels constitute the single most important solution for the transportation sector which today is almost entirely reliant on fossil fuels. This dependence will continue in the short to medium term and also in the long term biofuels will play an important role e.g. for heavy duty vehicles, ships, airplanes and in conjuction with other energy carriers such as electricity (hybrids).
Sustainably produced conventional biofuels already contribute significantly to increasing energy security, mitigating climate change and creating economic growth in rural areas around the world.
Advanced biofuels, which are based on waste products/residual products from e.g. agriculture and forestry, are expected to be commercialized in the coming years and these biofuels will further sustain this positive impact.

Question 2
What are the most important ethical challenges raised by the prospect of future generation biofuels?
Biofuels should be produced sustainably, i.e. with due respect for the environment and social consequences. Sustainably produced biofuels constitute an opportunity to supporting rural development in producing countries while at the same time reducing emissions of greenhouse gases and increasing energy security.

Question 3
Do you regard yourself as well informed about biofuels? Where do you get your information from?
Yes. There is ample information on most matters relating to the subject. An important exception is indirect land use change which is a science in its infancy.
Key sources of information include academic papers, conferences, industry partners, NGOs, government officials, media/journalists

3Drivers, hopes and benefits
The development of future generation biofuels is mainly driven by three factors: the need to mitigate climate change and achieve lower greenhouse gas (GHG) emissions; worries about energy security; and an interest in agricultural and economic development, both in the developed world and developing countries. It is hoped that future generation biofuels will be successful in addressing these concerns. There might also be other benefits to future generation 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 relative importance of the three mentioned main drivers will vary country by country and this is true for many initiatives / projects. It is therefore not possible to assign priorities in advance but in general substantial GHG savings is expected to be a main driver in many cases.
An important benefit not mentioned is the building up of knowledge about biorefining in general which will help introducing the ‘sugar based economy’ as a substitute for the ‘oil based economy’. Today a wide range of commodities including liquid fuels, chemicals and plastics are based on oil as a raw material. The roll out of biofuels support a wider development of technologies which eventually will enable us to produce these commodities in biorefineries using renewable materials instead of non-renewable materials as feedstock.

Climate change

If we continue to use fossil fuels at current and projected levels, the scientific consensus suggests that there will be a detrimental impact on the Earth's climate which may have global implications. To reduce the potentially destructive social, environmental and economic consequences of climate change, greenhouse gas emissions (GHG) need to be lowered. Some first generation biofuels were shown to generate only small reductions in GHG emissions in their lifecycle assessment. New approaches could do better in this regard. For example, lignocellulosic biofuels produced from agriculture or forestry residues have been estimated to have GHG savings of 80 to 90 percent, when compared to petrol or diesel. This assumes no land-use change has occurred in supplying the biofuel feedstock.1

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?

This is hard to predict without knowledge about the biomass and conversion pathway being used. However, in general cellulosic biofuels have very substantial GHG reductions (typically 85-90% compared to gasoline)

1 Renewable Fuels Agency (2008) The Gallagher Review of the Indirect Effects of Biofuels Production, available at: http://www.renewablefuelsagency.gov.uk/_db/_documents/Report_of_the_Gallagher_review.pdf, p24.

5 Energy security

Individual nations need a reliable supply of affordable energy – often referred to as energy security. Energy security can be increased by lowering energy consumption, using energy from a diverse mix of sources, and by producing energy domestically to reduce the need for imports.

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?

There is wide recognition that raising energy efficiency is a 'low-hanging fruit' that should be pursued across sectors. This can often be done at negative net costs. However, with growing demand for transportation services, this will not be enough in this sector. Diversifying the regions/countries from which energy for transportation is derived is therefore desirable. This can be done through import of feedstock for the production of biofuels or finished biofuels. With homegrown biofuels (based on domestically produced feedstocks) a country substantially reduces its risk exposure towards international oil markets. The latter approach is therefore a very attractive means to increasing energy security.

6 Economic development

New approaches to biofuel production could potentially create jobs and new sources of income both in the developed world and in developing countries – the so-called "Green Economy". This could in turn contribute towards improving infrastructure, and support overall economic and agricultural 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?

Both developed and developing countries can gain jobs and income when biofuel production starts up. Rural, agricultural areas have the most to gain.

Examples from the US

• Parts of the corn-producing US Midwest have experienced an economic upswing due to bioethanol (1). In 2008, the US ethanol industry created over 494,000 new jobs, most of them in rural areas (2)

Examples from the EU

• The impact of biofuel production on local employment in the European Union is 6–10 jobs per 1,000 tons produced (3)

Examples from the Brazil

• 800,000 direct jobs in the sugarcane industry were created - many of those in relation to the expanding ethanol industry. The increase of mechanized harvesting is raising demand for more skilled labor (4). In general, biofuel production generates jobs and income in developing countries, driving rural economies (5).

Increased demand for agricultural products

• The greater demand for agricultural products and the markets that biofuel helps create, give developing countries a chance to re-establish a healthy agricultural sector and foster rural development. Farmers in developing countries gain access to a bigger market for their crops – one that is less dependent on global commodity markets – where prices are often below production costs in developing countries (6)

Creating new markets

• 75% of the developing world's population lives in rural areas and approximately 86% of these people depend on agriculture for their subsistence. Biofuel production provides new market opportunities, with the potential to increase farming revenues or expand the productive capacity of existing cropland (6).

Creating new jobs

• Producing biofuels and bringing them to market create many jobs, particularly in rural areas (5). As biofuel production is likely to be far more labor intensive in developing countries, the number could be even higher

Biofuels can increase food security

• Biofuels increase the value of agricultural crops and can thus drive long term investments in agricultural production, which is needed for improved food security and reduction of poverty in the third world (4,5)

SOURCES:

1 Renewable Fuel Association, Outlook, 2008
2 Contribution of the ethanol industry to the economy of the United States. A report by LEGC LLC (for RFA) 2009.
http://www.ethanolrfa.org/objects/documents/2187/2008_ethanol_economic_contribution.pdf
3 United Nations University "Industrial and Environmental Biotechnology", 2005.
4 Sugarcane industry in Brazil. UNICA. http://www.unica.com.br
5 FAO. The State of Food and Agriculture, 2008.
6 IEA, Biofuels for Transport – An International Perspective, 2004.

7 Science, technology and research

Feedstock development and processing

In contrast to most first generation biofuel production, research is exploring the use of lignocellulosic biomass – the fibrous, inedible material from plants. Materials for lignocellulosic biofuels include non-food crops such as bushes/trees, and perennial grasses that can be grown specifically for biofuel production; as well as waste materials from agriculture, forestry and other urban sources. Another research area is the development of marine resources, such as algae, as biofuel feedstock.

In order to turn lignocellulosic feedstocks into biofuel end products, the feedstock first has to undergo pre-treatment to produce an intermediate form that is more amenable to conversion and reduces costs. Pretreatment can also make the material denser so it is more efficient for being transported. For example, sugars can be recovered from

lignocellulose using chemicals/enzymes to break the lignocellulose down (a process called lignocellulosis); carbon monoxide and hydrogen gases (a mixture known as synthetic gas or syngas) can be generated by gasification, and bio-oil can be produced by pyrolysis. Following pretreatment of the material, conversion processes and refining technologies are applied – including blending – so that the biofuel can be used for transport.

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?
Cellulosic ethanol will be commercialised in the coming years. Enzyme costs have been brought dramatically down over the last years to a level where they are well suited for commercial use. Costs for producing cellulosic ethanol in the US is now on par with conventional biofuels under optimal conditions. A number of demonstration plants to produce ligno-cellulosic ethanol are now operating or under construction in the EU and in North America (see http://www.grainnet.com/pdf/cellulosemap.pdf). Regular updates on the development of production facilities are provided by the International Energy Agency on its website (see http://biofuels.abc-energy.at/demoplants/projects/mapindex)

8Advanced plant breeding strategies, genetic modification and synthetic biology
Some of the new approaches to biofuel production involve advanced plant breeding strategies, genetic modification and synthetic biology. For example, advanced plant breeding strategies can be combined with conventional breeding to help produce new varieties of plants that express desired traits. Genetic modification can be used to introduce genes to produce favourable traits for biofuel production, such as higher yields or the ability to grow on land which cannot be used for food crops. Genetic modification is also used to enhance the biofuel production process. For example, microbes have been genetically altered to secrete enzymes which help break up the feedstock to enable easier biofuel processing and energy extraction. The emerging field of synthetic biology is aiming to develop entirely new means of producing biofuels. This might involve, for example, the specific design and construction of microorganisms (such as bacteria, yeast and algae) as biofactories producing biofuel: e.g. microorganisms which secrete fuel using waste water, sunlight, oxygen etc.

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
Novozymes supports the safe and sustainable use of gene technology in industrial processes, agriculture and health care.
Novozymes finds that gene technology offers a variety of benefits which can contribute to a sustainable development of society including:
•Better and cleaner industrial processes
•Extended use of renewable raw materials as substitutes for fossil raw materials
•More sustainable manufacturing processes for food, feed, fuel and chemicals
•Higher yields and lower use of pesticides in agriculture
•Development of new and better health care products

In order to ensure an adequate level of safety Novozymes supports that robust, science based regulation is in place for processes and products involving gene technology
Novozymes acknowledges the need for improving the general level of knowledge of biotechnology and gene technology and we will continue to provide information and engage in dialogue with stakeholders about benefits and risks in relation to our use of gene technology.

9 Intellectual property issues

Successful future generation biofuel production “from lab to tank” requires knowledge of the technologies involved at different stages of the production pathway, such as plant selection and production, growth/production of the feedstock, biofuel processing of the material, extraction of the fuel, and finally refinement and blending. Researchers are working to improve each step of the process. For example, advanced plant breeding strategies and genetic modification of feedstocks can be used to enhance yields or to make crops more resistant to heat or drought. Microorganisms can be genetically altered so that they secrete ‘digestive’ enzymes that enable more efficient processing of the feedstock into fuels. Several such technological tools and processes in future generation biofuel production have been patented or will be patented in the near future. Thus, if researchers, producers or companies want to use these technologies, they will have to apply and pay for a licence.
In addition, the future development of plants with desired traits may require access to plant material which is only available from other countries. Many developing countries, the main source of novel plant material, are raising concerns about intellectual property and in particular the appropriation of traditional knowledge by companies in the developed world. In some cases countries have adopted intellectual property legislation based on issues of access and benefit sharing in keeping with the Convention on Biological Diversity. The full implications of such legislation are yet to be understood.
These intellectual property and patenting systems protect the commercial interest of the patent holder, ensuring they can make a return on their often substantial initial investment. On the other hand, patents can hinder further research and create barriers to using the technology particularly for poorer populations and countries.
Given the rapid technological advances in the field, it is likely that questions regarding intellectual property, knowledge transfer and sharing of expertise will play an important role in future biofuel production.

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?

Intellectual property rights (IPRs) are a key driver of investment in R&D, innovation, and dissemination in the public and private sectors. According to data assembled by the World Business Council for Sustainable Development, patent rights are not a primary barrier to greater deployment of advanced technology in Least Developed Countries. Much more critical are:

- Economic viability
- Capital availability
- Supporting infrastructure
- Governance and regulatory stability
- Local capacity

Much of the advanced biofuel technology will be developed and patented by private firms. Published patent documents offer a vast accessible source of global technological information, partially also in local languages, on which others may build and so facilitating technology transfer.
However, the trend is for more and more of this technology development being done by industry leaders in emerging countries: Brazil, India, China, Malaysia, etc. This is a logical consequence of their evolution towards a knowledge economy, and a recognition of their current technical and economic strength in this sector.

10 Research and development (R&D)

Several elements of new approaches to biofuel production, including generation and biofuel processing of new feedstocks, are still being developed. A great deal of research is currently underway in the field.

Question 11

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

For cellulosic biofuels, very substantial R&D efforts have been carried out and enzyme costs have been reduced substantially as a result. Accordingly, what is needed now is not R&D in laboratory scale but process optimization in large scale plants.

Question 12

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

As mentioned, cellulosic ethanol is ready to be taken to commercial scale. Accordingly, what is needed now is not R&D in laboratory scale but process optimization in large scale plants.

11 Land use, environmental and food security and human rights

Land use

The amount of land that is used for biofuel production has increased significantly in recent years, and is predicted to increase dramatically over the next 20 years. Such land use has raised various concerns over environmental and food security, as well as human rights and health. The expansion of biofuel production has in the past sometimes resulted in local populations losing control of their land, and even in their removal from the land. Biofuels might be grown at the expense of basic food commodities resulting in local, and even global, food shortages and price rises. Even if biofuels are grown on land that is marginal for food production, this may result in the loss of natural or semi-natural biodiversity-rich areas, and endanger national parks and other protected areas, which in turn may result in severe impacts on critical ecosystem services (the benefits people derive from their ecosystem). Discussions around new approaches to biofuels have highlighted an awareness of these land use issues, and a desire to avoid them.
In addition, questions surround whether life cycle assessments of biofuels should consider the greenhouse gas (GHG) emissions released through indirect land use change (iLUC). Indirect land use change occurs when farmers direct existing cropland or crops into biofuel production. It is hypothesised that in response, farmers elsewhere in the world convert more forest land into cropland (e.g. for food agriculture), thereby releasing more carbon.

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?

Land is a scarce resource, but there is still untapped arable land – and with feasible yield increases, it is possible to meet projected food, feed, and fuel requirements without expanding agricultural land.
Current biofuel land use is low
• Current biofuel production uses less than 1% of global arable land (1), and according to the USDA, there is no evidence that the move to biofuels has driven any change in overall land use so far in the US (2)
Huge untapped potential
• Today, average agricultural yields in China, Brazil, Eastern Europe, and Africa are between 1/5 to 1/2 of average yields in North America and Western Europe, and in Africa only 11% of the potential arable land is used for food production (3)
Yield increases
• Growth in agricultural production is driven primarily by increases in yield. 75% of the additional food need over the next decades can be met by bringing the world's low-yield farms up to 80% of the efficiency of high-yield farms on comparable land (4)
Protects against soil erosion and desertification
• Enzyme technology enables the use of new feedstocks for bioethanol production such as drought-tolerant sorghum in tropical and subtropical regions, and mixed perennials such as willow, and grasses on marginal land in regions with temperate climate (5,6). With 1/3 of the Earth's land surface threatened by desertification and over 250 million people directly affected by desertification this is an important benefit
Biomass use
• Only a small amount of the available biomass is used today (7), and less than 6% of the biomass used for energy today is used for liquid fuels (3). Most of it is used at low efficiency – for example for domestic cooking and heating. Among the unfortunate consequences of this are deforestation and widespread respiratory diseases in developing countries
US biomass potential
• With only a minor change in land use, biomass will be able to cover 30% of current US gasoline consumption in 2030 (8,9)
EU biomass potential
• After meeting food and feed requirements, if all remaining agricultural land is used for biofuel feedstock (first- and second-generation), 20-50% of the projected fuel requirements of the transport sector can be covered (10)
SOURCES
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10 EEA, Technical Report (2007). G. Fischer et al: Assessment of biomass potentials for biofuel feedstock production in Europe: Methodology and results (IIASA-part of REFUEL study sponsored by the EC). Available online:
http://www.refuel.eu/fileadmin/refuel/user/docs/Refuel-D6-Jul2007-final6.pdf

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?

Developing countries often have minimal regulations in place to control land use change and protect sensitive areas, or have limited means to enforce them (e.g. illegal logging of hardwood in spite of international agreements). The economic development drive is often more important than preservation of the environment.
This problematic does not apply solely to biofuels current or future generations but to all use of land or biomass (including food) and needs to be in a coherent framework such as AFOLU - Agriculture, Forestry and Other Land Uses international agreements.
On the other hand, developing countries have the fastest growing needs for increased energy supplies, and development of biofuel capacity there can be done as part of an energy sector that is still growing rapidly. These countries also have 90% of the world's farmers, and creating a strategic, sustainable new category of markets for these farmers, if well managed, will be a major asset to address rural poverty, and the flow of economic value from the urban to the rural environment.

12 Question 15

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

The current science related to ILUC is still in its infancy and it should therefore not be used as basis for assessing GHG emissions savings associated with the use of various feedstocks for biofuels production. More research is definitely needed in this area before incorporating the science into policy making.

13 Environmental security

Current approaches to biofuel production can themselves have some effect on the environment. There have been criticisms over air pollution through activities like deforestation and the drying and burning of peatland. Water pollution can also occur through the escape of sediment and chemicals used in agriculture into water sources. This way, water catchment areas may be reduced. In addition, the use of large amounts of water, the destruction of land of high conservation value such as peatlands and rainforests, and the reduction in biodiversity and ecosystem services have been attributed to biofuel production.
Some of the new approaches to biofuels have been specifically developed to address these concerns. For example, enhancing crop yields, using waste materials or developing crops which grow under hostile conditions might reduce the need for resources such as water and land. This could relieve pressure on drinking water reserves, help to protect land of high conservation value, as well as potentially alleviate competition with food agriculture. Additionally, new approaches might benefit the environment, for example, by creating new habitats. On the other hand, lignocellulosic biofuel crops could actually be planted in areas of high biodiversity precisely because these have hitherto been unsuitable for crops. Moreover, there is a danger that trees in natural environments will be harvested unsustainably since this approach may often be cheaper compared to the management of plantations.

Question 16

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

Biofuels should – as all other commodities – be produced with due respect for the environment.

14 Food security

There have been concerns regarding the effect of first generation biofuel production on food security – that is the availability, price and accessibility of food at local, national and global levels. For example, there has been a debate about whether current biofuel production diverts agricultural resources (such as land and water) away from food production, potentially limiting local food supply. The diversion of US corn to produce fuel rather than food has also raised grave concerns over food

prices. In January 2007, the price of corn tortillas, a dietary staple in Mexico, rose by over 400 percent, prompting riots.2 Mexico is a net importer of corn.
New approaches to biofuels aim to avoid problems associated with food security. For example, feedstocks such as algae and lignocellulosic feedstocks might not compete with food.

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?
N/A

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?
N/A

2 Ziegler J (2007) The right to food: Note by the Secretary-General, available at: http://www.righttofood.org/new/PDF/A62289.pdf, p12.

15 Rights of farmers and workers
Discussions around new approaches to biofuels have highlighted an awareness of issues around the rights of farmers and workers both in the developed world as well as in developing countries. In first generation biofuel production, as with many other types of agriculture, there have been concerns that workers and farmers could experience inadequate working conditions and negative health effects, for example due to pesticide use. There have also been reports that workers have sometimes been provided with inadequate wages, particularly in developing countries. On the other hand, both small scale and large scale industrial biofuel production have given farmers and workers new possibilities of income and of developing their businesses.

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?
N/A

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?
N/A

16 Investment, policy and governance
Globally, current biofuel production takes place within many different business models, ranging from small scale domestic production (such as of biogas) to large scale industrial production (for example of bioethanol) in both developing and developed countries. Through their investment strategies, industry can shape to some extent how biofuel production develops. For example, they may be more likely to invest in new biofuel production pathways that are considered to be economically viable for large scale production. Such investment decisions also have a lot of influence on the way research progresses.

Investment in biofuels takes place within a policy context, which is shaped by the desire to mitigate climate change, improve energy security, and support agricultural and economic development without endangering environmental or food security or the rights of farmers and workers. National and international policies issued by governments and international institutions have the ability to promote or inhibit biofuel use and affect financial investment in research and development (R&D) from industry and the public sector. Such policies include greenhouse gas (GHG) emissions and bioenergy targets, incentives, subsidies and regulatory policies, research funding, and trade agreements.
Policies that affect biofuel production currently take the form of guidelines, legislation and agreements specific to biofuels as well as those from areas relevant to biofuel production such as agricultural practice, environmental protection, and technological standards. They operate at both domestic and regional levels.
Some policies have been revised, following concerns that some first generation biofuels might be harmful, and/or that policies might conflict with other regulations. The changeable nature of biofuel governance has created a lack of investor confidence.

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)?
As mentioned previously cellulosic ethanol will be commercialized in the coming years and what is needed to reduce prices further is process optimization in large scale plant at a size comparable to future commercial scale plants. However, constructing such large scale plants require substantial amounts of capital which private investors only will provide if appropriate framework conditions are in place. These framework conditions could consist of supply side initiatives such as production support (for a limited amount of years for the first plants) and loan guarantees / support for plant construction and demand side initiatives such as annual biofuels production targets (as the Renewable Fuel Standard in the US with separate targets for conventional and advanced biofuels).
17 Question 22
Which policy issues in relation to new approaches to biofuels would you like to bring to our attention?
See above.
EU's sustainability criteria are an important means to ensuring that biofuels counting towards the directive targets are sustainable. Such criteria should be extended to other commodities including the use of biomass for other bioenergy purposes (e.g. heat and electricity) in order to secure sustainability and a level playing field.

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?
Promotion of biofuels: Ensure framework conditions are in place in order to incentivize investors to invest in large scale plants
Supply side initiatives e.g. as production support (for a limited amount of years for the first plants) and loan guarantees / support for plant construction
Demand side initiatives e.g. as annual biofuels production targets with subtargets for conventional and advanced biofuels

18 Any other issues
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.

N/A

Thank you. We appreciate your participation in this consultation.
19