Royal Society of Chemistry

QUESTIONS ANSWERED:

Question 1

ANSWER:
Biomass is a versatile and important source of fuel, and also a rich feedstock for the chemical industry. In an attempt to alleviate fossil fuel usage and CO2 emissions, they have been cited as a strong alternative. The potential for increased exploitation of biomass resources is very large. However, the Royal Society of Chemistry (RSC) has severe concerns about usage of first generation biofuels (i.e. biofuels made from sugar, starch, vegetable oil, or animal fats using conventional technology) Depending on the method of production and resources used, production may require unfeasibly large agricultural land requirements, high energy processes and use of unsustainable feedstocks can result in poor energy balances and negative environmental impacts. In our opinion, second generation biofuels offer far greater potential for reducing cost and environmental impact, especially as they do not necessarily compete with food production. First generation biofuels have, and will continue to play, a major role in meeting legislative targets, such as the Renewable Transport Fuel Obligation, on a short time scale. With significant effort, second generation biofuels can have substantial market impact by 2015 and need to be deployed as soon as possible. Even so, it is important to acknowledge that biofuels alone cannot mitigate the environmental impact of transportation and power generation. Second generation biofuels can play a significant role but it will be alongside other measures to implement a wide range of renewable energy sources and to reduce our overall energy needs. Using life cycle analysis (LCA), issues such as environmental impact and long term feasibility can be assessed to determine how great a role they will play.

Question 2

ANSWER:
• Changes in land use in terms of its ecological, economic and social effect. • The diversion of land and crops from food production. • The use of imported fuels produced in regions with unregulated work practices or using unsustainable feedstocks. • The genetic modification of biomass to tailor properties for end use.

Question 3

ANSWER:
The RSC position and the opinions we express are a result of two extensive consultation processes. First, in April/ May 2007, a number of expert views from academia, research and technology organisations, the motor industry, the chemicals industry and other key stakeholders were obtained to compile a report on future energy options. [1] Second, during 2008 using workshops and online consultations, the RSC gathered expertise and views from members, non-members and a range of stakeholders worldwide. This process resulted in the publication of Chemistry for Tomorrow's World: A roadmap for the chemical sciences, a document that sets out priority areas in which the chemical sciences should be actively pursuing research. Both biofuels and the conversion of biomass were identified as key challenges. [2] The RSC is also involved in conferences and publication of works with regard to biofuels. [3] [1] RSC, Fuelling the Future - Summary Report Parts 1 & 2, 2007
http://www.rsc.org/ScienceAndTechnology/Policy/Documents/ftf.asp [2] RSC, Chemistry for Tomorrow's World: A roadmap for the chemical sciences, 2008
http://www.rsc.org/ScienceAndTechnology/roadmap/index.asp [3] Powering the World with Sunlight, A White Paper Describing the Discussions and Outcomes of the 1st Annual Chemical Sciences and Society Symposium (CS3), July 2009. International biofuels symposium as part of the 42nd IUPAC congress:
http://www.rsc.org/ConferencesAndEvents/RSCConferences/IUPAC2009/ScientificProgramme/Themes/e

nergy/biofuels.asp)

Question 4

ANSWER:
Which factors are going to be the most important in driving the development of biofuels in the future? • Research, development and demonstration of second generation biofuel technology. • Economic and fiscal incentives to encourage development. • Development of biorefineries to produce chemical feedstocks as co-products to fuel. • Public acceptance of biofuels must be considered a priority. • Life-cycle assessments must be carried out to ensure that biofuel production and use minimises CO2 emissions. • Research into ecosystem studies and diversity to provide important information on the impacts of biofuels, and to help predict impacts. To what policy concerns should priority be given? There is lack of cohesive, coordinated supporting strategies and regulations being set by government. A clear stance is needed to drive changes and encourage the adoption of biofuel technologies. In Europe, biofuels are typically financially supported by a reduction in fuel duty in order to make biofuels competitive, if not cheaper, compared to conventional fuels and enable businesses to make investment decisions. However, these fiscal incentives may be stifling the development of second generation biofuels by removing impetus to deliver lower cost technologies. A joined-up regulatory EU strategy is needed in order to support further sustainable development in this field. What advantages not mentioned here could and should future biofuel production aim to deliver? Along with the advantages listed (reductions in GHG emissions, energy security and rural and economic development) biofuel development also offers the possibility of new chemical sources which can be used as building blocks for pharmaceuticals and materials. The majority of biomass conversion processes produce low-volume side-products along with the high-volume fuels. These side products offer new functionalities and new opportunities for innovation to the chemical and biological sciences.

Question 5

ANSWER:
Which of the new approaches to biofuels will be most successful in generating GHG emission savings? Second generation biofuels offer the most viable biofuel route for realising GHG emission savings. In Europe, first generation biofuels currently offer around 50% reduction in CO2 emissions compared with conventional fuels. While first generation biofuels have established the market and infrastructure, it is vital that we move to second generation biofuels in order to achieve greater GHG emission savings. [1] Biofuels produced via biomass-to-liquid (BTL) processes (i.e. gasification of biomass followed by a Fischer-Tropsch conversion) can also offer significant CO2 emission reductions compared to conventional fuels and even other biofuels. [1] To maximise GHG reduction, it is vital that biomass conversion and biofuel production is carried out at local and regional, rather than national and international scales. Local generation is essential to reduce emissions related to transportation; this is especially true for transporting unprocessed biomass, where energy would be unnecessarily expended in carrying the inherent, but unproductive, moisture in biomass. How should these be encouraged? Commercialisation of these biofuels needs to be encouraged by both investment in research and in innovation. Clear targets have been set, both in European and UK policy, to encourage the use of biofuels. It may be necessary to now implement regulations concerning the production of the fuels, with particular focus on GHG emissions, the use of suitable feedstocks and the farming practices involved in their production. Financial incentives such as those currently available for first generation fuels are likely to be necessary to support early entry to market of second generation fuels. To foster development of biofuels, and the associated growth of the necessary crops, it is vital that there are clear benefits and incentives for the farming community to be involved. Production of a raw crop often leaves farmers economically worse off, [2] so biofuel production facilities which involve the participation of both farmers and the local community are far more likely to succeed. Are there any reasons why these new approaches should NOT be encouraged? Regardless of the fuel, further research and development is needed to improve processing. Cradle to grave life cycle assessments along with greater process efficiencies should aid in maximising the potential GHG savings. These approaches should only be encouraged once such issues have been dealt with satisfactorily. Efforts must also be invested in

ensuring that new approaches to biofuels do not result in further competition against food crops. Such approaches should be discouraged and alternative feedstocks identified. [1] European Commission, Directorate General, Joint Research Centre, Well-to-Wheels analysis of future automotive fuels and powertrains in the European context; WELL-TO-TANK Report Version 3.0, 2008 [2] David Morris, The Once and Future Carbohydrate Economy, The American Prospect, April 2006

Question 6

ANSWER:
Which of the new approaches to biofuels will be most successful in improving energy security? Biofuels alone cannot guarantee energy security. Widespread adoption of other renewable technologies, as well as reducing energy demands, will be vital if such a goal is to be achieved. The 1997 European Commission white paper on the use of renewable energy set targets requiring a six fold increase in the role of biomass in energy production by 2050. It also required significant increases in the use of wind, water and solar energies, with targets for wind and water set well above those for biofuels. [1] Of the biofuel options available, second generation biofuels based on lignocellulosic biomass, including agricultural, forestry and municipal waste; offer the greatest chance to improve energy security. Once processes are developed which can deal with the variation within such feedstocks, each region should have at its disposal a constantly available source of biofuels offering greater energy independence and security. How should these be encouraged? See question 5 Are there any reasons why these new approaches should NOT be encouraged? See question 5 [1] European Commission, White paper on renewable energy, 1997.

Question 7

ANSWER:
Which of the new approaches to biofuels will be most successful in supporting economic development? Regardless of the processing route, second generation biofuels offer the greatest potential to support economic development. The implementation of bioenergy has already been found to have positive socio-economic impacts in both developing and developed countries. Amongst developed countries, especially in the European Union, the image of bioenergy is swiftly changing in recognition of the potential environmental savings and economic benefits. Modern biomass-use systems have been cited as resulting in a better quality of life through increased rural employment and development. The use of second generation fuels will open up the market to a larger range of biomass feedstocks, further supporting development. On a national scale, economic growth is evident due to the increased employment, along with the energy independence offered by bioenergy production. [1] By processing biomass and producing biofuels close to the source, there is greater potential for economic benefits to be felt by the area. Localised processing will also help to strengthen rural economies. How should these be encouraged? As was mentioned in question 5, the commercialisation of biofuels needs to be encouraged by supporting research and developing suitable policy. Such policy should encourage local generation, both directly, through explicit legislation, and indirectly, through tight restrictions on GHG emissions which will increase with transport. The farming community may be sceptical of the benefits of switching from traditional crops to energy crops. Their inclusion in the process development elements should address their worries. It will also be important to highlight that second generation biofuels can be produced from waste or from crops grown on poor quality land; by complimenting, rather than replacing, current practices financial risk is minimised. Agricultural development organisations, farmers unions and regional development bodies must work together to facilitate this progress. Are there any reasons why these new approaches should NOT be encouraged? See question 5 [1] J. Domac, K. Richards and S. Risovic, Socio-economic drivers in implementing bioenergy projects, Biomass & Bioenergy, 2005, 28, 97-106

Question 8

ANSWER:
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? It is still difficult to determine which route to biofuels will become successful commercially. In fact, it is likely to be the case that several of the technologies will come into widespread use depending on the regional situation. Climate and soil type will determine the crops that are utilised, while the end use of the fuel will determine the process. Where a fuel for energy generation is needed, thermal transformations (e.g. gasification and pyrolysis) are sure to play a vital role due to the timescale on which the transformations occur and the suitability of the products. Further research and development is needed before identifying the lead transport fuel. It is possible that with further work pyrolysis oil could be easily upgraded for use in car engines, or that enzymes could be engineered for more efficient transformation of lignocellulosic biomass into alcohol type fuels such as ethanol or butanol. It would be unwise to choose a single option at this stage as this could impede progress in alternative areas. Over what timescales might such developments be commercialised? In order to make a significant impact on targets for GHG emission reductions and biofuel use, such developments must be commercialised in the next 5 years. Are there any risks associated with these developments? There are always risks related with investment in new technology. The production of second generation biofuels requires a significant capital investment to set-up. Should support for biofuels shift or the market shrink, the opportunity for revenue may decrease, resulting in poor returns on the investment. Facilities should be designed in order to ensure they are capable of rapid response to market demand, and capable to handle a diverse product portfolio. [1] It is also important to take full advantage of all the outputs of the biorefinery (e.g. chemicals and platform molecules) so that risk is minimised. By forming policies to support collaboration between biofuel producers and end users (e.g. car manufacturers, power plants, the pharmaceutical industry and chemical companies) the market for biofuels and biomass derived chemicals should be able to grow strongly. [1] SusChem, F3 Factory: Future. Fast. Flexible
http://www.suschem.org/content.php?pageId=3495

Question 9

ANSWER:
In order to maximise the output of land for biofuels it may be appropriate to use technologies such as advanced plant breeding strategies, genetic engineering and synthetic biology. In this way, feedstocks could be tailored to suit processes, for example, producing biomass with higher sugar content and lower levels of lignin to make it more amenable to biochemical transformation and land productivity improvements. This could result in less farming inputs and lower energy processes resulting in GHG savings across the supply chain.

Question 10

ANSWER:
What are the most important intellectual property and access issues raised in new approaches to biofuels? Intellectual property can be generated right across the supply chain from developing high-energy crop strains, to the production of the biomass itself and into processing and upgrading. In ensuring an adequate biomass supply, IP may be generated by designing systems based on growth of specific crops or under specific conditions, by improving biomass yield through reduced input to output ratios or developing new plant varieties. The pre-treatment and conversion processes themselves are possibly where the greatest opportunity for intellectual property lies. This is centred on production of “better” biofuels in terms of performance and/or cost, and providing more efficient or better yields from improved conversion methods. As the final stage, distribution offers further opportunities again in the design and logistics of networks (e.g. transport; depots, service stations, storage and delivery systems). Amongst these, intellectual property associated with processing and conversion will have the greatest impact. If new processing technologies are developed which are not shared or accessible for replication, it is likely that the most successful biofuel will become that with the greatest financial backing, negating the possible benefits for localised and rural economic growth. What is the best way of governing these? It will be difficult to govern access to intellectual property without going against competition laws and industrial operating standards. Here, success demands consistent policies and regulations. Policy should require the localisation of bio-fuel production due to the GHG emissions associated with nationalised production (biomass travelling more than 30km for processing is uneconomical [1]) and the need to encourage rural

development. [1] RSC, RSC response to Royal Society biofuels study, 2006 http://www.rsc.org/ScienceAndTechnology/Policy/Documents/2006/biofuelsstudy.asp

Question 11

ANSWER:
Success in biofuels research requires progress across diverse scientific disciplines (e.g. chemistry, biochemistry, biology, environmental science; biotechnology; plant sciences; environmental science; chemical engineering; etc.). Advancement requires a vision that drives the breadth of R&D innovation needed (with clear, timed goals), but also provides highly effective coordination. Cross-disciplinary research must be encouraged and supported through policy and funding. An independent body is also needed to drive common understanding and provide a set of standards on "sustainability" and calculation of GHG emissions. By establishing such a body it will be possible to make clear comparisons between the various competing methods. Society is inherently dependent upon petroleum based fuels in terms of infrastructure, engine design and established habits. R&D will be necessary to assist in the transition away from these towards systems more suited for biofuels.

Question 12

ANSWER:
Future biofuel strategies should be decided through consultation between those active in the field and policy makers. Those active in research can provide the most relevant input and advice on the future of the field, while policy makers can support those needs through legislation and funding directives. Such consultations could be facilitated by learned societies and industrial bodies. A secure and stable energy supply and environment should be amongst the top priorities of local and national governments, and as a result they must have a strong stance on the future of biofuels. Through the preparation of "Chemistry for Tomorrow's World: A roadmap for the chemical sciences" [1], the RSC consulted its members and the wider community as to where R&D for new approaches to biofuel be targeted. The following key challenges were identified as needing to be addressed: • Development of tools to measure the impacts of biofuels over the entire life cycle (life cycle analysis - LCA) – i.e. impacts of land use change • Genetic engineering of plants to produce appropriate waste products and high value chemical products • Genetic engineering of plants to grow on land (or sea) that is unsuitable for any food crops • Genetic engineering of plants with increased efficiency of photosynthesis, increased yields and requiring lower carbon inputs • Development of better pre-treatment technologies to improve the handling/ storage of biomass • Improved biorefinery processes o Improved modelling and analytical methods o Improved ways of hydrolysing diversified biomass and lignocellulose o Improved extraction of high value chemicals before energy extraction o Improved thermochemical processes, including developing better catalysts, microbes and enzymes o Improved flexibility of feedstock and output (electricity, heat, chemicals, fuel or a combination) • Development of methods of producing fuel from new sources such as algae or animal and other wastes • Development of ways of managing biorefinery waste streams so as to minimise environmental impact • Development of engine technology and improve understanding of surface technology to improve efficiency of biofuels for transport [1] RSC, Chemistry for Tomorrow's World: A roadmap for the chemical sciences, 2008 http://www.rsc.org/roadmap

Question 13

ANSWER:
Regardless of the process of biofuel production changes in land use or farming practices will be necessary, the matter for question is whether these changes are problems or opportunities. Second generation biofuels will use feedstocks such as agricultural and forestry residues along with crops grown on marginal land. As a result the impact on current agricultural land usage should be minimised. The removal of residues from fields and forest floors must be acknowledged in terms of nutrient loss and as such a balance must be established. When growing crops on marginal land, or land that was previously set aside, the economic benefits to the farmer are clear. Problems may arise in relation to biodiversity and the impact on established ecosystems as rough land is cleared and replanted. In such a case, legislation

should encourage the use of short rotation coppice, which has a positive effect on flora and fauna. The GHG emissions related with increasing agricultural productivity on the land must also be considered and acknowledged when considering the “green credentials” of a fuel.

Question 14

ANSWER:
Within the developed world lessons have been learned from the production of first generation biofuels with regard to food competition. As a result, subsequent generations of fuels should have minimal impact on food generation capabilities. Most developed nations also have strict laws in place to protect portions of the natural environment, removing the risk of encroaching on protected habitats. Within some developing nations, the opportunity to sell biofuels/biomass for fuel may result in loss of productive food land as higher-value energy crops are grown. There is also a risk of poor practices coming into action, such as unsustainable harvesting of biomass from endangered environments, e.g. replacing rainforests with palm oil plantations. [1] Legislation must be enforced in a strategic and connected manner to ensure that as the obligations under one international agreement (e.g. Kyoto Protocol to reduce carbon emissions) are met, others (e.g. Convention on Biological Diversity) are not neglected. [1] F. Danielsen, H Beukema, N.D. Burgess, F. Parish, C.A. Bruehl, P.F. Donald, D. Murdiyarso, B. Phalan, L. Reijnders, M. Struebig, E.B. Fitzherbert; Biofuel Plantations on Forested Lands: Double Jeopardy for Biodiversity and Climate, Conservation biology, 2009, 23, 348-358

Question 15

ANSWER:
Yes, it is important to include iLUC when evaluating the GHG emissions savings of new approaches to biofuels. If such emissions are discounted the real savings associated with the transition to biofuels may be over/under stated. As mentioned in question 11, the establishment of an independent body or group is necessary to monitor such emissions annually and investigate the link between any variations and increases in biofuel production. By placing the group within a department such as DECC or DEFRA an entire body of evidence with relation to emissions and changes in agricultural activity would be easily accessible.

Question 16

ANSWER:
Advantages • Reduced CO2 emissions from transport • Removes the need to explore new oil sources in remote environments • Encourage forestry & agricultural industry Disadvantages • Loss of biodiversity due to increased farming intensity • Changes in land use may damage the environment • Loss of agricultural/forestry residues resulting in soil nutrient loss How could harms for environmental security be dealt with? Clear and unified legislation across the board will be necessary to ensure that the environment is not damaged in attempts to reach targets set by other obligations.

Question 17

ANSWER:
New approaches to biofuels should have minimum impact on food security as they will be produced from non-food feedstocks (e.g. lignocellulosic biomass, algae) and on land not traditionally used for food crops.

Question 18

ANSWER:
Poor growing conditions and farming practices in developing counties already result in food security issues. Unless biofuel crops are carefully chosen, and the sector well managed, it is possible that food security may be further damaged by the growth of more lucrative energy crops. Brazil should be seen as

one example, not only to developing countries, of the effective management and implementation of biofuel production without impacting food security. [1] [1] S. Matsuoka, J. Ferro, P. Arruda; The Brazilian experience of sugarcane ethanol industry, In vitro cellular & developmental biology-plant, 2009, 45, 372-381

Question 19

ANSWER:
In developed countries, farmers' rights are well protected. New approaches to biofuels are therefore unlikely to raise problems related to rights of farmers and workers. In developing countries, where such rights are not as well established, it is possible that the intensification of agriculture may result in abuses of rights. International legislation must protect the rights of these individuals immediately in order to ensure that as the industry grows correct standards have been implemented from the start rather than applying them retrospectively.

Question 20

ANSWER:
See question 19.

Question 21

ANSWER:
Investment in new approaches to biofuels should be directed at R&D and commercialisation. Investments in basic science, to come up with the new ideas, will drive innovation in the future. [1] By establishing flexible commercial processes, it will be possible to incorporate the results of further research as it becomes relevant. Public-private partnerships should be used to drive this process. Such initiatives have a greater chance of success as a result of the government support they will receive for research and development. [1] R. Pike, P. Earis, Powering the world with sunlight, Energy & Environmental Science, Energy & Environmental Science, 2010, 3, 173

Question 22

ANSWER:
Government targets for biofuels lack cohesive, coordinated supporting strategies and regulations. These are needed to drive changes and encourage the adoption of biofuel technologies. Incentives which have been offered for first generation biofuels have made biofuels competitive, if not cheaper, compared to conventional fuels and enabled businesses to make investment decisions. However, we are concerned that fiscal incentives may have stifled the development of second generation biofuels by removing impetus to deliver lower cost technologies. [1] Funding for research, development and demonstration is available through the EU FP7 programme and Strategic Energy Technology (SET) Plan. A regulatory EU strategy is needed based on advice provided by key stakeholders. Communication with politicians and decision-makers is vital, as is information exchange and collaboration with environmental bodies. With an increasing focus on biofuels and the associated technologies, there is a need for a thorough and comprehensive definition of what is and is not a biofuel. Clarification would have obvious benefits when constructing regulatory frameworks. Policies should seek to: • Protect the environment by considering issues such as GHG savings, emissions associated with growth and processing and environmental impact of changes in land usage. This will need international standards and common processes to support the sustainable supply of biomass and biofuels. • Set achievable goals recognising competing market forces that impact on consumer choice, such as alternative products; cost; availability; and ease of use. • Encourage provision of biofuels offering greatest potential to lower greenhouse gas emissions and potential to compete with existing fuels on cost/performance. • Support collaboration between producers and end-users. • Recognise the need to stimulate R&D throughout innovation pipeline (i.e. from discovery, development, demonstrate, and deployment) and support it through directed funding. •

Improve public awareness about transport options and driver behaviour impact on greenhouse gas emissions. [1] RSC, Fuelling the Future - Summary Report Parts 1 & 2, 2007 http://www.rsc.org/ScienceAndTechnology/Policy/Documents/ftf.asp

Question 23

ANSWER:
As stated in question 22, policies to promote and incentivise new approaches to biofuels should follow a similar style to those used to encourage first generation fuels in the market. These incentives should be subject to review as progress in the field continues and be coupled with funding for further research and innovation. Developmental regulations should focus on the impact of the fuels of the entire life cycle, ranging from ecological and environmental impact to changes in farming practices. GHG emissions and energy consumption over all stages also needs to be a key factors when setting targets and restrictions.

Question 24

ANSWER:
We feel that the majority of issues which should be considered have been covered in this consultation.