BIOSCIENCES FEDERATION

RSC | Advancing the Chemical Sciences

Climate Change: Bioenergy

A response from the Biosciences Federation and the Royal Society of Chemistry to the Environment, Food and Rural Affairs Committee

February 2006

The Biosciences Federation was founded in 2002 in order to create a single authority within the life sciences that decision-makers are able to consult for opinion and information to assist the formulation of public policy. It brings together the strengths of 39 member organisations, including the Institute of Biology, which represents 42 additional affiliated societies (see Appendix). The organisations that have already joined the Biosciences Federation represent a cumulative membership of some 65,000 bioscientists and cover the whole spectrum from physiology and neuroscience, biochemistry and microbiology to ecology and agriculture. The Biosciences Federation is a registered charity (no. 1103894).

The Royal Society of Chemistry is the UK Professional Body for chemical scientists and an international Learned Society for the chemical sciences with some 43,000 members worldwide. It is a major international publisher of chemical information, supports the teaching the chemical sciences at all levels and is a leader in bringing science to the public.

Executive summary

1. UK capacity to produce biofuels (biodiesel and bioethanol) is limited to 5-10% of the total road transport fuel requirement without changes in the production of food crops but with use of exports and set-aside land.
2. Carbon savings would be greater in electricity production than in biofuels and so provision of land for this would exemplify ‘best use’.
3. There is much potential for the production of hydrogen by the highly efficient processing of biomass.
4. There are currently many options for the generation of energy from potential materials. The best of these, including the biorefinery approach, not only produces matter for power generation but also potentially valuable co-products.
5. Given the restriction of available land area, there is great potential in exploiting the extensive marine resources at the disposal of the UK for biomass production, a process which serves multiple beneficial roles beyond that served by the end product.
6. The potentials for bioenergy are unlikely to be exploited under prevailing economic conditions and sectorial approaches. There must be strong links between all those involved including academic research, agricultural production, industrial refining and end users be they public retailers or power companies.
7. Economic factors will drive the success of bioenergy so making this option competitive is essential. Research into the practicalities of scale, efficiency and logistics as well as the

creation of an appropriate long-term policy and finance framework based upon this research to support bioenergy in the UK is clearly needed.

8. A successful and essentially long-term emissions trading scheme would be an economic driver for companies offering energy with considerable CO_2 reductions. In addition, the lifetime of support mechanisms such as Renewable Obligation Certificates (ROCs) should be extended to encourage investment.
9. Economic support for ventures including Short Rotation Coppicing (SRC) which have returns after four years following high initial investment is vital for this approach.
10. A roadmap of what research, development and deployment is happening in the UK is critical in establishing the future strategy on biofuels. Cross party consensus towards a long-term direction is essential in realising the full potential possibilities presented.
11. Carbon emissions from the use of biomass or derived products is generally equal to that sequestered during the growth of the source material making the process carbon neutral. However, this depends crucially upon the energy used in processing and production, and the logistics and efficiency of agricultural, chemical, biochemical and engineering practices employed.
12. Achieving sustainability during production would be greatly helped by the publication of best practice guidelines for agriculture.
13. The impact of biofuel monocultures on ecology, for example oil seed rape, is likely to be detrimental, particularly if set-aside land is lost. However, SRC has positive impacts on flora and fauna with a variety of ecosystems supported.
14. Biomass is most effective in reducing CO_2 when the supply chain distance is minimal. This means that importing biomass should be considered carefully in this respect in addition to the ethical and security implications involved.
15. Continued involvement with international research programs is essential, particularly those which are principally similar to the conditions and situation of the UK. The work of the DTI in the area of bioenergy should continue and be built upon.
16. Any headway made in developing renewable energy policy should be mirrored in concerted efforts to improve user efficiency.

Response to specific questions

What is the real scope for biomass and biofuels to contribute to tackling climate change? What proportion of the UK's energy and transport needs could they provide?

17. Capacity for biodiesel is in the order of 5-10%of current diesel usage. This would require growing a significant additional quantity of oilseed rape and collecting and processing cooking oil. Bioethanol can be produced from sugar beet and wheat starch in the short term and lignocellulosic biomass in the longer term. Bioethanol can also be mixed with petrol as an oxygenate in low quantities (up to 10%) in unmodified engines, or as the majority component (e.g. E85 fuel as used in Brazil), however, this requires car engines to be modified. In the medium term bioethanol could provide between 5-10% of current petrol consumption. It should be noted that these fuels could allow the UK to meet the objectives of the Biofuels Directive, although much work is needed to realise this.

18. To exemplify this in a UK context, if you take the 3 million tonnes or so of wheat that is exported (and assume it is used instead for bioethanol) together with the assumption that all the UK set-aside land is used for oilseed rape for biodiesel production, then the UK could produce around 5% of its current Road Transport Fuel Requirement (38 million tonnes).

19. Electricity or heat from short rotation coppice provides between three and six times the CO_2 reduction per pound that can be obtained from rape methyl ester (RME) or bioethanol from

cereal crops used in transport fuels[1]. Given that land availability will be a long-term constraint, crops for transport fuels should logically only be grown where other energy crops cannot be grown or where the demand for heat and power is already met.

20. Biomass fired in dedicated plants, or co-fired in coal burning plants, has a reasonable potential for Combined Heat and Power (CHP) generation, an estimate would be that around 5% of electricity could be generated by such sources in the medium term. It is interesting to note that a number of UK power stations (e.g. International Power's Rugeley plant) are currently successfully co-firing imported biomass (such as imported olive waste and milled palm nuts from Malaysia)[2]. Gasification for power production in engines and turbines is fairly well developed with several demonstration plants in Europe. Gasification can also be used for production of synthesis gas (syngas) from which hydrocarbon fuels may be produced via Fischer-Tropsch synthesis. Syngas may also be used to produce methanol which can be converted at high efficiency into gasoline and diesel for transport via Methanol to Gasoline (MTG) or Mobil Olefin to Gasoline Distillate (MOGD) processes. Alternatively fast pyrolysis directly gives a liquid at up to 75 weight% yield which can be used in engines and turbines for power production. The resultant liquid can be stored or transported and delivered to a large processing plant for gasification and synthesis of liquid transport fuels. This can be operated giving economies of scale that are difficult to achieve with gasification. A further incentive is the potential for production of chemicals from the resulting pyrolysis liquid for example levoglucosan (a glucose derivative). These types of chemical are currently not hugely valuable as they largely rival those sourced from refining fossil fuels but, being feedstocks for the chemical industry, their value would be expected to rise as fossil fuel resources diminish.

21. There is potential for hydrogen to be produced by refining the by-products of agriculture and forestry and in fact any type of biomass by gasification. This process is highly efficient and research is progressed to a level that large scale production would be possible given the correct economic climate and necessary infrastructure[3].

22. There is considerable potential for strategic development of solid biofuel use for electricity but this makes long-term economic sense only where forestry residues are also used. Short rotation coppice (SRC) (or the use of giant grasses e.g. *Miscanthus*) may offer an element of security with Renewable Obligation Certificates (ROCs) and SRC planting grants encouraging SRC plantings in the short-term but discounted cash flow issues go against SRC. This is due to the high initial investment costs and harvesting 4 years after planting rather than regular yearly income associated with annual crops.

23. The production of biogas is not as conducive to efficient transport in the same way as biofuels considering current infrastructure. However, because it can be generated by any source of organic waste by a range of low to high tech conversion options over a variety of scales it is suitable for immediate consideration in micro-generation style options. Larger projects are unlikely to gain sufficient capital in the current investment climate in addition to compromising optimal carbon dioxide savings by sourcing material from wide catchment areas. In terms of emissions this approach makes use of gases which would otherwise escape from landfill and efficient use of the energy potential of waste, reducing carbon output when compared to incineration.

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[1] Mortimer, N. D., Cormack, P., Elsayed, M. A., and Horne, R. E. (2003). Evaluation of the comparative energy, global warming and socio-economic costs and benefits of biodiesel. Final report from the research unit school of Environment and Development, Sheffield Hallam University for the Department for Environment, Food and Rural Affairs. Report No. 20/1.
[2] Department of trade and industry (2005). Best Practice Brochure: Co-Firing of Biomass (Main Report). Report no. COAL R287.
[3] Babu, S. P. (2004). Biomass gasification for hydrogen production – Process description and research needs. A report from the International Energy Agency Thermal Gasification Task Force.

24. As terrestrial contributions are greatly limited by the finite area of land available under any scenario, it is essential that we do not ignore the potential of the marine environment as a source of biomass for methane production. Research by the Scottish Association for Marine Science (SAMS) has demonstrated that macroalgae may be cultivated easily, grow prolifically (increasing biomass by 10% per day under optimum conditions) and sequester carbon. In addition, the aquaculture of seaweeds reduces contribution to eutrophication of the seas (removing nitrogen from the water for growth) and therefore may be used to mitigate the effects of sewage effluent and industrial sources of nitrogenous waste such as those originating from fish aquaculture, contributing to the maintenance or improvement of biodiversity.

25. Research in the USA into anaerobic fermentation during 1977, showed that seaweed yielded methane at a higher efficiency by weight than any other source of biomass [4]. At the time, research was halted because the technology of aquaculture was not advanced enough to withstand offshore conditions and fossil fuel derived gas prices were sufficiently low to discount methane as a practical alternative. Since then, practices in the mariculture of seaweed have advanced significantly and the price of gas in the UK continues to rise as supplies are diminished. Scotland is home to over 90% of UK aquaculture by value and volume and the SAMS have developed methods to produce large volumes of seaweed. As well as using specially developed structures and techniques for the production of seaweed inshore, additional potential lies in coupling the development of this area of aquaculture with current and future offshore installations such as wind farms. These potentials have been illustrated by demonstration projects in Germany, showing that cultivation methods for appropriate seaweeds may be applied to coastal conditions typical of those locations used for offshore wind power generation[5].

26. Essentially, research funding is needed to marry well developed marine culture skills with the latest developments in anaerobic digestion to test UK seaweed species for suitability in methane production. Only when there has been a complete investigation into the whole process from culture to methane production will the potential for this approach truly be measured. It is clear that the opportunity to expand the possibilities presented by bioenergy into the substantial marine resource governed by the UK should not be overlooked.

27. It is quite obvious that a roadmap of what research, development and deployment is happening and needed in the UK is critical in planning future strategy and determining the real potential for UK bioenergy.

How cost-effective are biomass and biofuels in comparison with other sources of renewable energy?

28. This will depend upon scale, agricultural practice, energy efficiency of process, utilisation of crop residues, transportation requirements and other parameters.

29. Biomass costs nearly twice as much as coal on an energy value basis. Conversion requires lower capital costs due to the relative absence of pollutants. The disperse nature of biomass means that small plants of typically up to 25MWe equivalent will be the maximum that can be built unless there is massive importation of biomass. That is why the direct liquefaction route of pyrolysis liquid production and transportation is so economically attractive.

[4] http://www.oceansatlas.com/unatlas/uses/EnergyResources/Background/Biomass/B1.html

[5] Buck, B. H., Buchholz, C. M. (2005). Response of offshore cultivated Laminaria saccharina to hydrodynamic forcing in the North Sea. Aquaculture, 250: 674-691.

30. At sufficiently large scales of operation (for example above 50 MWe equivalent) and sufficiently low biomass costs (for example below £30 per dry tonne), bio-electricity and transport fuels could be produced competitively.

31. Co-firing biomass (in a ratio of around 1:9 biomass to coal) in conventional coal burning power stations means power companies can sell the resulting power for a higher cost through the renewable obligation certificates scheme (ROCs)[6].

32. Production costs for biodiesel are around 30-40p/litre (depending on scale of production) and are a little less for bioethanol but only at large scale production levels. The 20p/litre excise duty relief is key to their success. The economy of scale is an important factor in comparing the potential of biodiesel and bioethanol as the energy needed to refine bioethanol is higher than that of biodiesel. This arises from the fact that bioethanol from fermentation is a dilute solution of alcohol in water. To remove this water requires heating in the process of distillation. This offers a significant opportunity for scientists and engineers to develop energy efficient processes (such as pervaporation membranes) that could significantly reduce the energy required in this process[7].

33. The use of biomass for energy is most efficient where the source of fuel and the demands are within economically viable distances of each other. In the Scottish example, 80% of energy needs are attributed to the supply of heat and transport fuel, roles that the products of anaerobic seaweed digestion at numerous locally based centres may part fulfil in coastal communities.

34. It is important to consider that "cost-effective" cannot be the main criterion before the facts are well established. Once the technology is viable, completely different cost equations will arise.

How do biofuels compare to other renewables, and with conventional fossil fuels, in terms of carbon savings over their full life-cycle?

35. In general CO_2 emission can be lowered considerably as CO_2 released on combustion should equal the CO_2 fixed as during plant or algae growth. However, this depends crucially upon:
    - **Energy** of the process to convert biomass to biofuel, i.e. the more energy intensive the process (assuming energy derived from fossil fuel) the greater the CO_2 emitted over the lifecycle of the biofuel. The biggest contributor to the high carbon balance is the fertiliser assumed to be needed for production of biomass [7]. However, this is not applicable in the case of seaweed aquaculture.
    - **Transportation.** The further a feedstock or biofuel has to travel (assuming that transport is using conventional fossil fuels), the greater the quantity of CO_2 emitted across the lifecycle. It is worth noting here that in comparison to other renewable sources including wind where the source of generation is effectively at site, in the case of biofuels the source must be delivered and stored from a site of production. Counter to this, sustained supply of biofuels to generation plants negates the issues of intermittency faced by such environmentally relient sources and bolsters security of supply. Aquaculture in conjunction with offshore wind installations could reduce the transportation element of the carbon balance during the production of seaweed as biomass.
    - There is a significant opportunity for the **chemical and biochemical sciences** and **engineering** to make significant positive impacts within biofuel synthesis

[6] http://www.forestmachinejournal.com/articles/Drax.pdf
[7] http://www.eere.energy.gov/biomass/net_energy_balance.html

in terms of reducing energy and time, increasing yield, improving quality and reducing cost. Therefore there is a need to support the underpinning R&D science base.

36. Currently, different studies give different results and much depends on the Scoping and Systems Boundaries used for comparative Life Cycle Assessments (LCAs) of fossil versus biofuels. In terms of Carbon savings, assumptions made on the credits given for the by-products (rape-meal, glycerol, straw for biodiesel; distiller's dried grain with solubles (DDGS) and straw for bioethanol) have major impacts on conclusions.

37. The assumption should be that CO_2 produced from recycled carbon is different from CO_2 released from sources hitherto long term stored.

Not all biomass is equal—potential carbon savings depend on, for instance, farming practice. What can be done to ensure energy crops are sustainably produced?

38. Best practice guidelines for farmers with a specific focus on minimising energy and costs would be an excellent starting point. The National Non-Food Crops Centre (NNFCC) and the many other centres of excellence such as Rothamsted Research, The Institute of Grassland and Environment Research (IGER) and the University of Southampton are well positioned to coordinate such an activity (with appropriate funding). A second point of note is that where feasible, by-products of biofuel production (e.g. wheat straw or sugar beet pulp) should be made into co-products or burned in order to maximise the energy efficiency of the system and offset costs. A third key point is to optimise the production of fuels and chemicals using concepts of biorefineries. The biorefinery approach is one in which the current petrochemical method of refining crude oil is applied to biomass, for example wheat, to produce fuel and additional chemical products and so optimising crop use.

39. Whilst it is technically possible to improve the energy balance of a crop, this would be difficult to enforce and is probably best left to the market. For example, urea as a source of nitrogen is cheaper than ammonium nitrate. However the former is energy intensive in its production compared to the latter.

40. Similarly, it is important to realise that for bioethanol production only 20% of the energy inputs occur on farm - approaching 80% relate to the manufacturing process. In contrast, biodiesel requires a lower energy input during manufacture. Although, as discussed earlier in the case of bioethanol, the potential to reduce the energy of the process should be seen as a challenge to scientists and engineers.

41. There should be development of the best of the options in bioenergy available known now with proper R&D programmes for others. The production of seaweed, for example, has the potential to not only assimilate eutroficating nutrients from industry, agriculture and sewage effluents, but also contribute to the sustainability of other marine activities including the aquaculture of fauna which are sources of excess nutrients, primarily nitrogen. This is in addition to sequestering carbon as they grow.

What impact will UK Government and EU actions have in increasing demand for, and production of, biomass and biofuels?

42. Both the Biofuels Directive and the Renewables Obligation should be powerful tools for increasing the demand for biomass and biofuels. However, to catalyse UK based biomass and biofuel industry, local production must be favoured over importing significant quantities of biomass and biofuels from abroad. Legislation and policy tools offer an

opportunity to encourage best practice in biomass and biofuel production and should encourage practices that minimise energy requirements, cost and environmental impact. Legislation could also be applied in promoting the use of biomass co-products (such as wheat straw) to be used as a means of generating bioenergy and biofuels; the use of such co-products would reduce the need for planting specific energy crops. A successful and long term Emissions Trading Scheme would be an economic driver for companies offering energy with significant CO_2 reductions.

43. Underpinning this is the fact that however extensive the support measures and disincentives for fossil energy, industry will only adopt and implement these new technologies if there is a clear commercial and financial case for investment.

44. Government changes to excise duties and other financial mechanisms have a huge impact on production of biofuels. In the case of biomass production for generation, there are no immediate perceived financial incentives in comparison to those made available to nuclear or wind powered generation.

What level of financial and policy support do bioenergy technologies require in order to achieve the Government’s targets for renewable energy?

45. Long-term, cross Governmental consensus on UK energy policy is required that defines clear targets for bioenergy within a clear regulatory and incentive framework. A UK bioenergy industry can only thrive if such a long-term framework is in place (this applies across the board in terms of energy policy).

46. The current situation is that the amount of support is fairly attractive to investment, but the duration is insufficient for long term investment e.g. Renewable Obligation Certificates (ROCs) have a limited life that is considered insufficient for larger investments. There is also particularly high risk aversion (compared to countries such as the USA for example) in the UK which makes venture capital particularly expensive and makes companies reluctant to invest.

47. Currently there is little incentive for private investment in R&D relating to the potential relating to bioenergy so for governmental targets to be met in this area; this must be addressed. To reverse this trend a number of steps could be considered including progressing government schemes to applicable, end-product phases; the promotion of private-public partnerships at all stages of the process especially among companies currently reliant upon fossil fuels; the creation of a competitive environment for biofuel research via appropriate policy and economic mechanisms.

48. For example, on the basis of energy yield per hectare, woody biomass as a fuel for heat and power is much better than biodiesel. However, this crop has not developed because, unlike biodiesel, there is no existing supply chain of the sort found in France, Germany and Italy. It's difficult for the supply chain to develop because it requires small producers to form into cooperatives or other organisations which are large enough to deal with large customers, primarily the power companies. The stimulation of partnerships between the agricultural and energy sectors would clearly aid progress in this area.

49. In the area of marine aquaculture, immediate investment in researching the potentials of inshore and offshore resources as a source of bioenergy at appropriate scales would do much to open up the debate past the limitations of terrestrial production. In the future,

provision of robust law and rights governing co-management of dual use areas of marine estate will be necessary in enabling best use of productive positioning[8].

What impact might an increase in energy crops in the UK and the rest of the EU have on biodiversity, production of food crops and land use and the environment more generally?

50. This depends on what you grow and how you grow it. Any change in agricultural practice will undoubtedly have an impact upon biodiversity in some respect and it is important that we understand the implications of such changes as part of decision making processes. Again, it is important to stress the potential of agricultural and forestry co-products for bioenergy production (e.g. bioethanol from lignocellulosic biomass and all the other conversion technologies). Best practice guidelines for growing and processing bioenergy crops would be a valuable tool in reducing environmental impact by maximising product use.

51. Increasing wheat and oilseeds for liquid biofuels will have limited impact on biodiversity and on balance is likely to be detrimental if set-aside land is lost. SRC in contrast has very positive impacts on flora and fauna. The 3 year cutting cycle presents canopies of differing heights encouraging different ecosystems for each of the 3 years.

52. In considering the possibility of cultivating crops under an SRC regime, there are a number of disadvantages. Unlike arable crops (including non-food crops), SRC incurs establishment costs in the first two years and no output until year four. Establishment costs must therefore be subsidised to enable the aversion of cashflow implications. SRC has a triennial harvesting pattern rather than annual with knock-on effects to producers. In addition, the costs of removing SRC and reverting the land back to agricultural production are considerable. This means that under the current market influences, SRC is unlikely to be grown on land other than that required by the EU to be set-aside which ensures that income exceeds the cost of production.

Does bioenergy production constitute the best use of UK land for non-food crops? Should UK and EU policy focus on increasing domestic production of energy crops and biomass, or are there merits in importing biomass for energy production, or raw feedstock or refined biofuel, from outside the EU?

53. Importing biomass needs to be carefully balanced from both an environmental and economic perspective. Biomass usually, but not always, contains a significant proportion of water and therefore transportation costs (in terms of both money and fuel) essentially relate to transporting that water. Again, it is important to stress that the CO_2 balance of bioenergy sources can be tipped in an unfavourable direction through poor supply chain management and high levels of fertiliser application. Importing completed biofuels such as bioethanol and biodiesel, may be feasible as the energy density of such materials is much greater and therefore transportation is less critical on the CO_2 balance. However, if we become reliant upon imported biofuels then there is an issue over security of supply, the situation in which we currently find ourselves regarding fossil fuels. In summary, it is sensible to minimise the distance a source of bioenergy has to travel throughout its supply chain, therefore local production is favourable. This means that small scale conversion plants will tend to dominate which has an adverse impact on economics of scale and costs of biofuels. The merits of a biorefinery approach to biomass utilisation may offer some mitigation to the high costs of bioenergy products through production of added value chemicals.

[8] Buck, B. H., Krause, G., Rosenthal, H.(2004). Extensive open ocean aquaculture development within wind farms in Germany: the prospect of offshore co-management and legal constraints, Ocean & Coastal Management, 47(3-4), 95-122.

54. The best and most profitable non-food crops are those which provide products which through their functionality, environmental impact, health inputs and cost, will replace petrochemical products e.g. vegetable oils as lubricants or surfactants etc. When this is applied to bioenergy crops, the potential to fulfil other collateral needs must be considered. These roles may encompass the growing of bioenergy crops in areas unsuitable for alternative use including saline, dry or polluted conditions and the possibility of deriving high-value pharmaceuticals from said crops. Currently the Worlds total production of all biological oils and fats is no more than 20% of the 600 million tonnes of diesel used annually in road transport alone. In this scenario it is best left to the market to decide on comparative use of land for non-food crops for fuels or for other industrial uses. However, ethical conflict issues over (1) provision of land for non-food crops in a world with a growing population (2) the destruction of virgin areas of habitat for bioenergy provision should not be disregarded in discussions on bioenergy imports.

What more can be done to make more efficient use, as an energy source, of the by-products of agriculture and forestry (e.g. wood waste and other organic waste)?

55. Much can be done to make more efficient use of by-products of agriculture and forestry. A few examples are cited below:

- Burn residues in dedicated biomass CHP plants for both electricity and heat generation (either for industrial or housing projects).
- Co-fire residues that are grown in close proximity to coal fired power stations.
- Gasification of residues to make either fuel gas (e.g. Hydrogen) or syngas (which can be used to make hydrocarbons, methanol and other fuels).
- Pyrolysis of residues to make either bio-crude, charcoal or syngas.
- Chemical or biochemical production of renewable bulk and speciality chemicals to increase the overall value of the system through biorefineries.

In addition, longer term availability of ROCs would help for example in allowing companies to plan long term investment options.

56. The biogas route deserves serious investigation, development, and consideration, keeping in view the potential to return the residue with nutrients, to fertilise the crop. It would be useful to quantify the amount of methane likely to be produced from deliberate "capture" schemes, compared with what is continually being produced by ongoing biological processes.

What lessons can be learned from other countries' experience in the production and use of bioenergy?

57. We can use the examples of other countries in the drafting of best practice guidelines for the growing, processing and use of biomass and biofuels. It is of course important that such guidelines are relevant to the conditions and situation of the UK. Widespread participation in the international R&D programmes such as the IEA Bioenergy organisation[9], which receives UK and EC funding, will help to exploit these opportunities. The DTI Global Watch programme has already operated at least three missions on bioenergy to improve knowledge and technology transfer. The DTI has also organised trade missions to other countries to promote bioenergy in the UK.

58. Biodiesel has developed as a transport fuel purely because the supply chain, as for food oils, was already in place. It has suited France, Germany and Italy to promote biodiesel

[9] http://www.ieabioenergy.com/IEABioenergy.php

because it can supplement agricultural incomes in a way which is legitimate under CAP. Were it not for these aspects, biodiesel would not have developed. Research into these supply chains and how the UK could implement them would be worth considering. An additional source of bioenergy is being explored via current programmes operational in Sweden[10] that utilise industrial waste from livestock processing to produce biogas for transport and heat. In addition there is opportunity to use such wastes in co-firing power stations, however current UK legislation pertaining to health risks prevent such options[11].

59. We should not over-estimate the potential to produce energy crops. Land is the major limiting resource and bioenergy should be seen as only part of a renewable policy that involves use of wastes, wind, wave, solar and other renewables combined with commitment to international research into future technologies including the ITER project due to begin operation in 2016. These steps should be taken in addition a concerted effort to improve user efficiency.

Openness

60. The Biosciences Federation is pleased for this response to be publicly available and will be shortly placing a version on www.bsf.ac.uk. Should the Environment, Food and Rural Affairs Committee have any queries regarding this response then they should in the first instance address them to Dr Caroline Wallace, Science Policy Advisor, Institute of Biology, 9 Red Lion Court, London, EC4A 3EF email: c.wallace@iob.org.

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[10] http://www.svenskbiogas.se/
[11] House of Lords Science and Technology Committee (2004). Renewable Energy: Practicalities, Volume 1: Report. Box 5: Chicken litter vs chicken feathers, p. 35.

Appendix

Member Societies of the Biosciences Federation

Association for the Study of Animal Behaviour
Biochemical Society
British Andrology Society
British Association for Psychopharmacology
British Biophysical Society
British Ecological Society
British Lichen Society
British Mycological Society
British Neuroscience Association
British Pharmacological Society
British Phycological Society
British Society of Animal Science
British Society for Cell Biology
British Society for Developmental Biology
British Society for Immunology
British Society for Medical Mycology
British Society for Neuroendocrinology
British Society for Proteome Research
British Toxicological Society
Experimental Psychology Society
Genetics Society
Heads of University Biological Sciences
Heads of University Centres for Biomedical Science
Institute of Animal Technology
Institute of Biology
Institute of Horticulture
Laboratory Animal Science Association
Linnean Society
Nutrition Society
Physiological Society
Royal Microscopical Society
Society for Applied Microbiology
Society for Endocrinology
Society for Experimental Biology
Society for General Microbiology
Society for Reproduction and Fertility
Universities Bioscience Managers Association
UK Environmental Mutagen Society

Additional Societies represented by the Institute of Biology

Anatomical Society of Great Britain & Ireland
Association for Radiation Research
Association of Applied Biologists
Association of Clinical Embryologists
Association of Clinical Microbiologists
Association of Veterinary Teachers and Research Workers
British Association for Cancer Research
British Association for Lung Research
British Association for Tissue Banking
British Biophysical Society
British Crop Production Council
British Grassland Society
British Inflammation Research Association
British Marine Life Study Society
British Microcirculation Society
British Society for Ecological Medicine
British Society for Parasitology
British Society for Plant Pathology
British Society for Research on Ageing
British Society of Soil Science
Fisheries Society of the British Isles
Freshwater Biological Association
Galton Institute
Institute of Trichologists
International Association for Plant Tissue Culture & Biotechnology
International Biodeterioration and Biodegradation Society
International Biometric Society
International Society for Applied Ethology
Marine Biological Association of the UK
Primate Society of Great Britain
PSI - Statisticians in the Pharmaceutical Industry
Royal Entomological Society
Royal Zoological Society of Scotland
Scottish Association for Marine Science
Society for Anaerobic Microbiology
Society for Low Temperature Biology
Society for the Study of Human Biology
Society of Academic & Research Surgery
Society of Cosmetic Scientists
Society of Pharmaceutical Medicine
UK Registry of Canine Behaviourists
Universities Federation for Animal Welfare

Additional Societies represented by the Linnean Society

Botanical Society of the British Isles
Systematics Association